DESCRIBING KNOWLEDGE FROM SEMANTIC NETWORK

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Technical Report MS-CIS-83-33

Spring 1982

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ABSTRACT

This document is a study of linguistic means and strategies that a human speaker implicitly uses when providing information that is new to his/her interlocutor. It may lay the ground for the design of an eventual interactive computer system exploiting a knowledge base to brief a user in English. The specific work reported is an experimental investigation of natural language generation rethorics in describing knowledge encoded as a semantic network. The knowledge representation language used is Kl-One, a data structure specification language defining conceptual objects organized in a network.

1.0 MOTIVATION

This project is a contribution relevant to the study of interaction between a knowledge base and a user of this knowledge base in a situation where s/he needs to be briefed about parts of the stored information. Typically, a help system explaining some concepts in a certain context upon request, and conveying information in natural language is the hypothetical system whose design this experiment could benefit. Its purpose is to try to outline the strategies which a person describing some piece of knowledge follows while producing natural language sentences that are a linear representation obtained from two dimensional knowledge encoded in a semantic network.

The processes involved in generating description of knowledge are of the decision-making sort. Decisions must be made about WHAT to say, HOW to say it (i.e., following which order, using which words and connectives, and in what syntactic form), and also HOW MUCH to say. The latter point is a crucial one as far as as extracting a small subset of a relatively large knowledge space. What to say is also of great importance as most descriptions are far from being complete. Thus, depending on a number of factors such as the user's knowledge state, past ans present foci, and overall goals related to using a specific body of knowledge, some features and procedures may -- and should -- appear more or less salient. Finally, the universal problem of choice of syntactic form to generate for deep structure semantics is also present. In a help system framework, it may be helpful (sic) to explore whether the way appropriate syntax is obtained at surface level narrows the otherwise numerous strategies for producing natural language.

2.0 BACKGROUND

The project stands close to performing the sort of analysis that was done by Kathy McKeown [McKeown-81] to support her TEXT system. Although seemingly similar, its intention differs from McKeown's in some points due in most part to the differences in the underlying knowledge representations. Her approach does indeed address the very same issues as the ones we investigate. However, the relatively simple knowledge representation scheme that she used somehow prevented the analysis from going beyond rough conceptual relationships. Thus, a deeper and closer look at rhetorical techniques (after Grimes [GRIMES-75]) is enabled for refined structured inheritance.

McKeown's analysis tries to characterize discourse organization relations which constitute the strategies for describing the content of some body of knowledge (in that case, a database.) Four such schemas are found by her to recur in descriptive discourses; namely, identification, attribution, constituency, and comparison/contrast. These enter as guidelines in the building of descriptive sentences requested by three classes of questions; viz., definitional ("what is..."), informational ("what do you know about..."), and differential ("what is the difference between...".) The key to McKeown's approach is to relate each question to some "relevant knowledge" via the rhetorical schemas and use of focal movement as identified by Candace Sidner [Sidner-79], and further refined for generative purposes by McKeown.

I believe McKeown's analysis to be very insightful, and I am curious to see whether her rhetorical schemas can be valid for Kl-One. For example, the attributive mode of description is restricted to attribute/value structures. There is no possibility for role interaction and inheritance to differentiate descriptive paths. Also, it is interesting to see if and how "relevant knowledge" is circumscribed. In providing a definition, contextual selection of internal and external information is also to be non-trivial in a virtual knowledge lattice (e.g., do we want to use only local information or global structures? -- myopic focalization vs. generalization whenever possible.) Finally, comparing/contrasting is supported by a richer metric in a Kl-One net.

Another study of text generation specifically from a Kl-One net is done by David McDonald [McDonald-81] in his Ph.D. dissertation. He is concerned, in a general way, with generating natural language from semantic deep structures independently of the underlying representation formalism. Along with many other schemes, Kl-One is used as an example to support investigating text generation about meta-knowledge. In other words, McDonald's exercise with Kl-One is one describing a Kl-One taxonomy as such, rather than interpreting the encoded knowledge. The strategy used is a straightforward depth-first exhaustive enumeration of concept descriptions in terms of their constituents. McDonald's concern was to concentrate in fluent paragraphing and minimal redundancy.

3.0 THE EXPERIMENT

A data collection experiment was set up. Subjects were to be presented a set of questions about entities of an given Kl-One network. The questionnaire was laid out so as to contain one question on top of each page, the rest of the page being left as answer space. Subjects were asked to answer the questions in their order, using English exclusively of diagrams and other graphical means. Mention was specifically made that material for answering be drawn exclusively from the given net. Each subject was left with the questionnaire and the attached copy of the same network for a week, after which the completed questionnaires were collected.

3.1 The Network

A Kl-One network encoding knowledge about an operations research model of a production, distribution, an inventory system was designed (P/D/I system). The domain was chosen arbitrarily. The network was dense enough to appear non trivial, and sparse enough to be drawable and readable. It contained 17 concepts, 32 roles, and 2 structural descriptions (which were "role-value maps"; i.e., stating that some roles were to be filled by the same fillers). This network appears in the appendix. *

Two versions of the network were drawn. A version had nodes tagged with their actual names in the application domain, and another version's concepts and roles were tagged with dummy labels (C1 to C17, R1 to R32). The purpose of this was to investigate the significance of names in the semantic network. It has indeed been claimed by Kl-One designers that names in a Kl-One net are transparent to the captured epistemology, and thus could as well be absent. Their only acknowledged role is a mnemonic labelling from or for a Kl-One programmer.

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* All my indebted thanks to Anne Froehling from the School of Landscape Architecture for her expert help in making the blue prints.

3.2 The Subjects

There were six available subjects for the experiment. It was indeed a pre-requisite that participants be familiar the Kl-One semantics in order to interpret the encoded knowledge. Hence, the relatively scant number of subjects.

These were divided into two groups of three. A first group was first given a questionnaire and its related Kl-One net where names were used. The other half was presented the label questionnaire and network. That constituted the first round of the experiment. After collection, a second round was distributed to the same subjects, with a questionnaire whose questions were identical to the previous ones except for the fact that entities in the attached network were referred to differently. The intent was, of course, to trap any effect in the order of presentation. As it later appeared, no discernable difference was to be detected.

Of the six available participants, only four provided usable data. A subject in the first group had but a fuzzy recollection of Kl-One, and thus the answers provided were semantically erroneous and incomplete. On the other hand, one of the participants in the second group failed to complete the experiment. As a result, a number balance was preserved. In the examples given in the next sections, the four subjects are identified by letters (B and D for the first group, and E and N for the second).

3.3 The Questions

Each questionnaire consisted of ten questions (see appendix for a sample questionnaire). Following McKeown, three types of questions were devised. They were presented in the following order. First, differential questions, then informational questions, and finally definitional questions.

There were five differential questions. Three were of the form: "what is the difference between C1 and C2" and two were of the form "what is the relationship between C1 and C2", asked in this order. The concepts chosen for the contrasting queries were respectively brother concepts (i.e., sharing a parent),and cousin concepts (i.e., sharing an ancestor). Of the two comparison queries, one involved two concepts previously contrasted, and the other involved concepts of different genealogy.

Three informational questions ("What do you know about C") intended to span all cases where C has no parent, has both parent and progeny, and has no descendant. The purpose here was to capture the different (if at all) rhetorics used.

Finally, two definitional queries ("what is C") concluded the questionnaire. In the first one, C was a top concept, and the second one C was a bottom one with a rich structure (with, in particular, two structural descriptions).

4.0 DATA ANALYSIS

This section goes into the detail of the collected data analysis. Of course, one could draw an immense number of interesting observations from the data, exploring along various dimensions, using all sorts of analytical techniques, looking for miscellaneous types of evidence. It is far from any contention of mine to present a complete, exhaustive, or even conclusive analysis. The following are points which struck my attention as I reviewed the data I obtained as described. I do believe much more could be said with more time or by other observers.

Examples are given in a standard format. In descriptions containing no names (hence referred to as label descriptions), the original labels (C1-C17, R1-R32) have been systematically replaced by their corresponding names between square brackets. It should be kept in mind that the questions and the network seen by the subjects when giving these answers, as well as these answers themselves, contained but dummy labels. The substitution was done by me a posteriori for comparison and legibility purposes in the analysis, and also to ease reading of the examples in this report. In the examples, "LD" stands for "Label Description" and "ND" for "Name Description". The reader is strongly encouraged to refer to the sample net in the appendix to make full sense of the following examples and comments.

4.1 Differential Questions

4.1.1 Syntactical Form -

The syntactic constructs used when contrasting or comparing two concepts are very few. The "while/whereas" construct, or variation of it, is strongly predominant. Alternatively, use of pairs of identically structured short sentences is also made to indicate difference or similarity. The following examples illustrate each type of syntax:

(Q1) <u>What is the difference between a sink node and a source node?</u>

(B) A sink node has no outgoing links, while a source node has no incoming links.

(N) A sink node is a node that has exactly zero outgoing role fillers. A source node is a node that has exactly zero incoming role fillers. (etc...)

Parenthetical structures, whether circumscribed by commas, parentheses, or hyphens, are used as a handy tool to insert orthogonal information in a linear construct. Instances of this are:

(Q2) <u>What is the difference between an [inventory process] and a [distribution process]?</u>

(B) Both are types of [process], but there are two differences. A [distribution process]'s type of [from] -- called an [origin] -- is a [place], while a [inventory process]'s type of [from] -- called a [start] -- is a [inventory date]. The second difference is in their [to]s. A [distribution process]'s type of [to] -- called a [destination] -- is a [place], while a [inventory process]'s type of [to] -- called an [end] -- is again a [inventory date].

(D) What distinguishes [distribution process] from its superconcept [process] is that the fillers of [origin] and [destination] (modifications of [start] and [end] respectively) must be instances of [place], whereas what distinguishes [inventory process] from [process] is that the fillers of [start] and [end] (modifications of [start] and [end] respectively) must be instances of [inventory date].

It is interesting to note that the parenthetical syntax is used more systematically in label description mode rather than in name description mode. This contributes to the observation that label descriptions are in general syntactically more awkward. Indeed, it appears that the absence of meaning in the labels tends to affect the syntax, often forcing telegraphic constructs to overtake grammatically sound English. An extreme case looks like:

(Q3) What is the difference between a transportation net and a distribution system?

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(E) LD. [Distribution system] has differentiated the [site] of [p/d/i
        system], which is a modification of the [vertex] of [network],
        into [production site] and [consumption site]. Also it has
        [distribution] which is a modification of [activity] of [p/d/i
        system].
        stop.
        [distribution system] has
                [production site] (diff of [site] of [p/d/i system]
                        (mod of [vertex] of [network]))
                [consumption site] (same)
                [distribution] (mod of [activity] of [p/d/i system]
                           (mod of [network]))
        [transportation net]  has
                [medial] (mod of [medial] of [transhipment net]
                        (diff of [vertex] of [network]))
                [sink] (from [medial] (diff of [vertex] of [network]))
                [source] (same)
        Basically, [distribution system] has 2 [vertex]s and
        [transportation net] has 3 [vertex]s. They both have the
        same sort of structure but with different specialization
        restrictions.

    ND. A transportation net has two kinds of vertices (sink nodes and
        source nodes), while a distribution system's vertices are called
        production sites and consumption sites. The arcs in a
        distribution system are called distribution.
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4.1.2 Rhetorical Form -

A striking rhetorical difference arises between label descriptions and their respective name conterparts in the way contrast is explicated. In a label description, relation to a common superconcept is first introduced before detailing internal similarities and differences. When names are used, however, descriptions are often taking advantage of their semantic imports, yielding relatively compact sentences. Of the same flavor is the tendency to relate internal attributes of two concepts to compare via their corresponding super-attributes in label descriptions, versus more direct "chunking" differentiation when names are present. In the following examples, these points are illustrated. Each pair of descriptions corresponds to a different subject. The question is Q1.

(B) ND. A sink node has no outgoing links, while a source node has no incoming links.

LD. They are both types of [node], but whereas a [sink node] cannot have any [outgoing]s (while a [source node] can), a [source node] cannot have any [incoming]s (while a [sink node] can).

(D) ND. A sink node has no outgoing links, whereas a source node has no incoming links.

LD. What distinguishes [sink node] from [node] (its superconcept) is that role [outgoing] is modified so as to have precisely 0 fillers, whereas what distinguishes [source node] from [node] is that the role [incoming] is modified to have precisely 0 fillers.

When asked about the relationship between two concepts, the subjects, in either types of descriptions, provide reference to the superconcept as a unifying feature supporting similarity. This somehow comes as a reinforcement, and often stands alone in the eyes of many to constitute an appropriate answer to "what is the relationship ... ". One can judge by the following example -- to be contrasted with answers to Q1.

(Q4) What is the relationship between a sink node and a source node?

(B) ND. Both are nodes, but whereas a sink node has no outgoing links, a source node has no incoming links.

(D) ND. Both are nodes.

(E) LD. They are both [node]s.

(N) LD. Both are [node]s. The only concepts that can be both a [sink node] and a [source node] are those which have zero [outgoing] fillers AND zero [incoming] fillers.

4.2 Informational Questions

4.2.1 Syntactical Form -

Sentences tend to be normalized to main and relative clauses. It is not too surprising as it this syntax somehow reflects Kl-One inheritance (i.e., a C1 is a C2 whose R is a C3). Itemization and "respectively" are also recurrent syntax.

4.2.2 Rhetorical Form -

As explained before, three informational questions ("what do you know about...?) were devised, respectively asking information about a top concept (i.e., having no superconcept), a middle concept (i.e., having both super and subconcepts), and a bottom concept (i.e., having superconcepts but no subconcepts). The collected data concerning answers to such questions convincingly show a consistent uniformity in rhetorical form. One can thus observe that (cf. following examples):

(1) A top concept is examplified by an itemization of the immediate subconcepts.

(2) For a middle concept, the immediate superconcept is first given, then the examplifying subconcepts.

(3) A bottom concept is defined in terms of its superconcept.

It is also mentioned when the concept being asked about acts as a value/restriction for some other roles in the given knowledge base. Also and again, label descriptions tend to be more clumsy, more dispersed, and harder to parse than their name counterparts. The following complete two samples are good illustrations of all the foregoing points.

(Q8) What do you know about node?

(B) ND. All the vertices of a network are nodes. Nodes come in four varieties: sink nodes, medial nodes, source nodes and stages. The first three constitute the different kinds of vertices in a transhipment net.

LD. [Node] is a top-level concept that is not further classified as a type of anything. There are four types of [node]s, three of which differ as to whether or not they have any [outgoing]s and [incoming]s, and the other ([stage]) differs as to what kind of thing its [outgoing]s and [incoming]s are constrained to be. Its [outgoing]s and [incoming]s (called [output] and [input] respectively) must be [process]s -- a type of [link]. The [outgoing]s and [incoming]s of [sink node], [medial node] and [source node] can be any type of [link]s. A [sink node] doesn't have any [outgoing]s, a [source node] doesn't have any [incoming]s, while a [medial node] has both.

(D) ND. There are four kinds of nodes: sink, medial, and source nodes and stages. Nodes have outgoing and incoming links.

LD. [Node] has two roles, [outgoing] and [incoming], which must be filled by instances of [link] (if they are filled at all). [Node] has four subconcepts, [sink node], [medial node], [source node], and [stage]. [Sink node], [medial node], and [source node] result from further restrictions on the number of fillers of [outgoing] and [incoming], while [stage] results from a further restriction on the KIND of thing that may fill [outgoing] and [incoming] (i.e., [stage]s rather than [link]s).

(Q6) What do you know about process?

(B) ND. A process is a link whose start is a stage and whose end is a stage. (The start and end of a process correspond to the from and to of a link, respectively.) There are two types of processes: distribution processes and inventory processes. These differ in whether their start and end stages are places or inventory dates.

LD. [Process] is a type of [link] whose [from] and [to] must be [stage]s. (No other types of [link] are given). [Process]'s [from] is called its [start] and its [to] is called its [end]. There are two types of [process] -- [distribution process] and [inventory process] -- which differ as to whether their [start] and [end] are both [place]s or both [inventory date]s.

(D) ND. Process is a kind of link whose from and to nodes are start and end stages.

LD. [Process] is a subconcept of [link] whose roles [from] and [to] must be filled by [stage]s. There are two kinds of [process], [distribution process] and [inventory process] which differ as follows: in [distribution process], [start] and [end] are filled with [place]s, whereas in [inventory process], [start] and [end] are [inventory date]s.

(Q7) What do you know about place?

(B) ND. A place is a stage whose output (or "out-stream") is a distribution process and whose input (or "in-stream") is a distribution process as well.

LD. [Place] is a type of stage, whose [output]s and [input]s are constrained to being [distribution process]s, rather than more general [process]s.

(D) ND. Place is a kind of stage whose input and output processes are in-stream and out-stream distribution processes.

LD. [Place] is a subconcept of [stage]. [Place]'s roles [out-stream] and [in-stream] restrict [stage]'s roles [output] and [input] (respectively) so that they are only filled by instances of [process].

4.3 Definitional Questions

There are two questions of type "what is C": one concerning a top-concept, and one about a bottom concept. The general interpretation made by the subjects is quite close to the informational query's. However, descriptions seem to be more limited to internal structure, and no mention is made about roles typed by the queried concept via value/restriction links. For example,

(Q9) What is a network?

(D) ND. A network has at least one vertex (which is a node) and may have any number of arcs (which are links).

(E) ND. A network is 1 or more vertices and zero or more arcs.

(N) ND. A network is a concept that must have at least one vertex role which must be a node, and zero or more arc fillers which must be links.

4.4 Referential Form

Most of the subjects answered label questions and name questions at a different level of reference. That is, whenever named, Kl-One entities are referred to directly as conceptual entities in the subjects' worlds, whereas labelled entities are conceived as quoted objects (in the LISP sense). This is recurrently happening throughout the experiment for all types of questions, In the following example, the question is Q3. This point is also illustrated by all previous examples as well (contrast ND and LD answers given by subject D in all examples above). *

(D) ND. A transportation net is a transhipment net that has no medial vertices, whereas the vertices of a distribution system are differentiated into production and consumption sites, and the arcs are differentiated into inventory and distribution activities (which are processes).

LD. A [transportation net] is a [transhipment net] which has exactly 0 fillers for [medial], whereas a [distribution system] is a [p/d/i system] whose [site] is filled by a [place] and whose [activity] is filled by a [process].

A specific observation regarding references in differential answers appears to explain some aspects of the variations between name and label descriptions. As pointed out earlier, descriptions with names are relying on the semantic contents of given names. This is most obvious as often concept names are in fact nominal compounds. Thus, in the differential question involving concept names sharing some noun, implicit relations are taken for granted that are made explicit in the corresponding label descriptions. This can explain the

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* D is the subject who gave answers where difference in referential levels is most striking. However, this difference exists, though less systematic or conspicuous, in other subjects' productions.

compactness of name descriptions, together with common superconcept references in label comparisons (when the shared noun is that very common superconcept; e.g., sink node and source node, inventory process and distribution process). This can be observed in most examples given above. When the concept names to be compared have no common part, or if the shared noun does not bear obvious referential meaning to take advantage of, then very little variation exists between answers in either mode, in general. See, for instance, the following example.

(Q5) What is the relationship between a distribution system and distribution process?

(B) ND. The activity of a distribution system is a distribution process.

LD. A [distribution system] has [activity]s -- called [distribution]s -- all of which are [distribution process]s.
or
A [distribution process] is what any of [distribution system]'s [distribution]s must be.

(D) ND. A distribution system is a kind of network whereas a distribution process is a kind of link.

LD. A [distribution system] is a kind of [p/d/i system] whereas a [distribution process] is a kind of [process].

(E) LD. [Distribution process] is the value restriction of [distribution system]'s [distribution].

ND. A distribution process is the distribution activity in a distribution system.

(N) LD. A [distribution process] may be an [arc] filler for a [distribution system] (i.e.,an [activity] or [distribution] filler).

ND. A distribution role filler (in any) of a distribution system must be a distribution process.

Finally, a very interesting observation can be made about ways of mapping Kl-One constructs into referential compounds. In fact, one could extrapolate from the gathered data the following general rules implicitly used in making up referential constructs.

(Rule 1) Reference to an attribute of a concept may be made as the combination of the rolename qualifying the value/restriction name. Examples of this are: "incoming link", "from node", "input process", "end stage".

(Rule 2) Reference to an attribute of a concept may be made as the combination of the rolename qualifying the rolename of a super-role it modifies, when the super-role has more than one sub-roles. Examples of this are: "production activity", "medial vertex".

(Rule 3) Reference to an attribute of a concept may be made as a genitive construct of the form: "concept's role". Examples are: "network's vertex", "stage's input".

(Rule 4) The above three rules may be combined simultaneously. For example: "a distribution system's distribution activity process".

5.0 SYNTHESIS

In this section, I summarize the main observations developed in the foregoing analysis. The main dimensions along which this analysis concentrated are (1) the impact of the semantic import of names in the semiotics of generation of natural language descriptions from a semantic network, (2) the rhethorics underlying answers to differential, informational, and definitional queries, and (3) the general syntactical strategies used in producing these answers.

A strong conclusion regarding the first dimension is that names _do_ seem to help in wording descriptions. The most obvious way is making them more compact, advantage being taken -- explicitly or implicitly -- of the semantic content of substantives in the mind of the subjects. Another effect of English name use is the naturalness in the style. Less redundancy, longer sentences, and ellipsis (syntactic or semantic) thus appear as overall features of name descriptions. On the other hand, descriptions of entities referred to by dummy labels specify as many times as needed identical nominal references, use a greater number of shorter sentences or phrases, and spell out all relevant properties.

The strategies involved in answers to the three kinds of questions investigated seem also to follow noticeable patterns. Differential queries are answered by specifying the discrepancies in the shared attributes. Less often (indeed, more in label descriptions than in name descriptions), unshared attributes are mentioned, if at all. Informational answers, in the collected data, behave in a very consistent manner. A concept is introduced in terms of its superclass where characterizing differences are specified, then, if any, all immediate descendants are given as examples. Finally, definitional answers concentrate more in the internal structure of the defined concept.

Syntactically, very little variation exists. Differentiation is limited to "while/whereas" constructs, and descriptions are almost exclusively of the form: main clause followed by relative clause. It is felt that this was somehow predictable as this syntactic construct reflects the essence of role inheritance in a Kl-One net. A very interesting point can be observed concerning the making of referential compounds. Indeed, Kl-One role structures seem to map into very specific constructs. Four "rules" can thus be extrapolated from the data.

6.0 CONCLUSION

The data collection and analysis performed in this project show interesting results. The main observations are that descriptions of information encoded in a semantic network follow rhetorical patterns which can be characterized depending on the type of questions and the position in the net of the described entities. It is found that when entities bear English names, natural language productions are more compact, more "natural", and syntactically more elegant. Finally, Kl-One provides a natural mapping of role structures into specific nominal compounds that can be used for referential purposes.

In a closing remark, I want again to make the point that more dimensions could be exploited from the collected data, and more observations could be made *. I purposefully limited myself to the above discussion, as the features underscored appeared to me of primer importance for a study in aspects of natural language description generation.

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* The complete set of collected data is on the VAX in [HASSAN.CIS679] DATA.RNO, and stays available for anyone willing to look at it.

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- APPENDIX -

The following are the ten questions constituting the questionnaire with fully spelled names. The label questionnaire was similar except that concept names were replaced by dummy labels (also the associated Kl-One net; and hence, the subjects' answers).

(Q1) What is the difference between a SINK NODE and a SOURCE NODE?

(Q2) What is the difference between an INVENTORY PROCESS and a DISTRIBUTION PROCESS?

(Q3) What is the difference between a TRANSPORTATION NET and a DISTRIBUTION SYSTEM?

(Q4) What is the relationship between a SINK NODE and a SOURCE NODE?

(Q5) What is the relationship between a DISTRIBUTION SYSTEM and a DISTRIBUTION PROCESS?

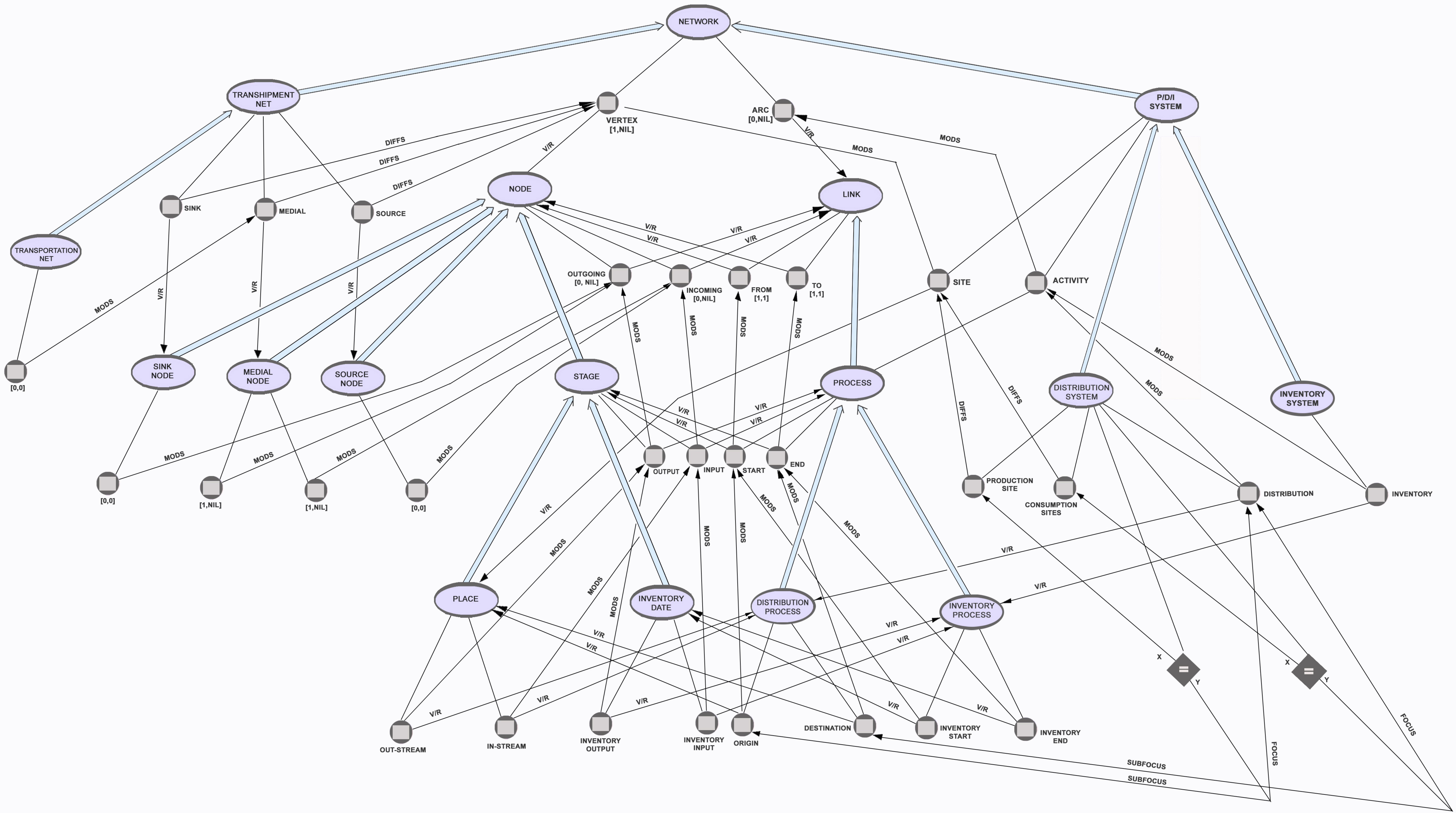
(Q6) What do you know about PROCESS?

(Q7) What do you know about PLACE?

(Q8) What do you know about NODE?

(Q9) What is a NETWORK?

(Q10) What is a DISTRIBUTION SYSTEM?


NETWORK
TRANSHIPMENT NET
VERTEX [1,NIL]
ARC [0,NIL]
P/D/I SYSTEM
NODE
LINK
SINK
MEDIAL
SOURCE
TRANSPORTATION NET
OUTGOING [0, NIL]
INCOMING [0,NIL]
FROM [1,1]
TO [1,1]
SITE
ACTIVITY
[0,0]
SINK NODE
MEDIAL NODE
SOURCE NODE
STAGE
PROCESS
DISTRIBUTION SYSTEM
INVENTORY SYSTEM
[0,0]
[1,NIL]
[1,NIL]
[0,0]
OUTPUT
INPUT
START
END
PRODUCTION SITE
CONSUMPTION SITES
DISTRIBUTION
INVENTORY
PLACE
INVENTORY DATE
DISTRIBUTION PROCESS
INVENTORY PROCESS
X
=
Y
X
=
Y
OUT-STREAM
IN-STREAM
INVENTORY OUTPUT
INVENTORY INPUT
ORIGIN
DESTINATION
INVENTORY START
INVENTORY END
DIFFS
V/R
MODS
SUBFOCUS
FOCUS