An Investigation of the Existing Essential Problems and Their Major Causes of the Current Hypertext System: With Emphasis on Hierarchical Semantic Relations

ハイパーテキスト・システムの本質的問題とその主な原因：階層的意味関係を中心にして

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Abstract

本稿では，現在のハイパーテキスト・システムにおける本質的問題とその発生原因について，主として探索実験例をもとに考察した。

最初に，ハイパーテキストおよびその発展経緯を概観・紹介し，現在のハイパーテキスト・システムの本質的な問題点として，探索上の方向喪失（disorientation）と知的オーバーヘッド（cognitive overhead）を取り上げた。次にそれらの問題点をハイパーテキストの機能を備えたCD－ROM百科事典（Bookshelf '94）を例にして検証し，その主な原因について考察した。その考察の中では，意味記憶（semantic memory）を応用した5つの指示語によって，ノード間の関係を表現する階層的意味関係モデルの提案を試みながら，ハイパーテキスト・システムにおける本質的問題の解決策についても簡単に言及した。

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1. Introduction

The idea of the hypertext is not new. It is derived from the idea represented by the sentence "The human mind operates by association" in the article "As We May Think" [01] written by Vannevar Bush, published in July 1945. Since then, in these past 30 years, a great deal of effort has been made in the development and improvement of the hypertext system by taking advantages of advanced technology of various fields, especially computer science, information science, artificial intelligence and cognitive science. In addition, the traditional data models, namely *relational, hierarchical* and *network* data model, were accepted among the designers as efficient database management tools for information retrieval and these methods are combined with the hypertext system.

Today, the applications of hypertext enable the user to access knowledge sources more actively and in many different ways. They make it possible for the user to add or amend the information in order to make it more personally meaningful and to build personal knowledge structure on the computer. In addition to this, they are applied to the Internet as Mosaic which is a software to retrieve multimedia information from WWW(World-Wide Web) server. However, experiences in using the current hypertext system have revealed some problems which will divert user's attention from the real work to be carried out because of the essential two problems, namely *disorientation* and *cognitive overhead.*

The main point of the research reported in this paper is that the linking structure of hypertext should reflect the structure of human memory in order to get over the existing essential problems. In this sense, through semantic network with the ability to capture the inherent meaning of the data from the real world, it may be possible to make hypertext mimic human memory.

In this paper I attend to introduce a hypertext system and to consider the relations between the essential problems of the current hypertext system and human memory structure, putting an emphasis on the navigation process, with the intention to investigate some possible ways to solve the problems on the basis of hierarchical semantic relation.

In addition to this, I attempt to propose a simple model of describing semantic relations between nodes of the hypertext system using some indicators such as ISA (is a kind of) and to discuss the effectiveness thereof in the hypertext system.

2. The Development of the Hypertext System

2.1 Definition of the Hypertext System

As Conklin points out that "one problem with identifying the essential aspects of hypertext is that the term 'hypertext' has been used quite loosely in the past 20 years for many different collections of features" [02], different authors define hypertext in different ways. Most of the definitions, however, include the term "non-sequential" or "non-linear". For example, Karen Smith describes that "in a general sense, hypertext means non-sequential reading and writing" [03]. Jokab Nielsen describes that "Hypertext is non-sequential; There is no single order that determines the sequence in which the text is to be read." [04]. In addition, Ted Nelson who coined the term hypertext, describes as follows: [05]

Hypertext is the combination of natural-language text with the computer's capacities for interactive, branching or dynamic display, when explicitly used as a medium. Or, to define it more broadly, "hypertext" is the generic term for any text which can not be printed (or printed conveniently) on a conventional page, or used conveniently when bound between conventional covers. "Non-linear text" might be a fair approximation.

While the term "hypertext" is defined in Iwanami's Dictionary of Information Science as follows: [06]

Hypertext is a data structure of computerized text which is not restricted to one dimensional text structure as represented on paper. In general, the hypertext consists of nodes with a certain organized information, and links with the attribute of connecting the nodes in network form.

A key point which characterizes hypertext is not one dimensional text, or non-linear text structure. A simpler way to explain this feature is to contrast hypertext with traditional printed text which is essentially linear such as that in books or articles. Each book or article is composed being based on the assumption that the reader will start with the first component and proceed to the last component (although there are some other approaches which can be regarded as non-linear such as footnotes or references intended to provide the reader with pointers to additional information). On the other hand, the order of reading the hypertext is determined freely in accordance with each user's interest.

Hypertext has been referred to as a non-linear or non-sequential text stored in a computer. Each individual fragment (chunk) of information is called a "*node*", and an indicated available transition between nodes is called a "*link*". The link defines the relationship between nodes and it transfers from one topic to another. On the computer display, a node corresponds to a window (See Figure 1). Windows on the screen are associated with a unit of objects in a database, and links are provided between these objects, both graphically (as labelled tokens) and in the (hypertext) database (as pointers). [02]

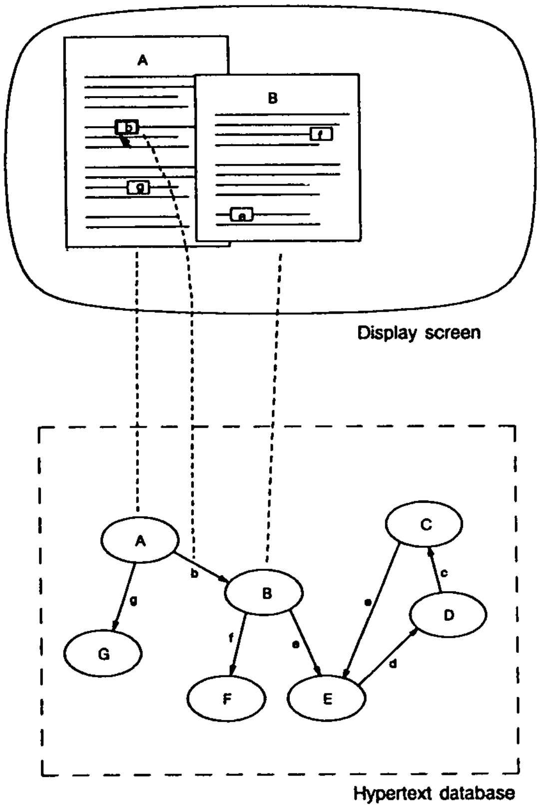

Figure 1. The correspondence between windows and links on the display, and links in the database. [02]

In this sample of Figure 1, each node in the hypertext database is displayed in a separate window on the screen when requested. The link named "b" in window "A" has been activated by a pointing device, causing a new window named "B" to be created on the screen and filled with the text from node "B" in the database (Generally, links can have names that are different from the name of the node they point to) [02].

In the hypertext system, the user can not only search and access to expected information but also add new information as consisting nodes and create new relations (links) between nodes in order to make it more personally meaningful or to build the user's own knowledge structure.

In summary, I would say that the hypertext system can be defined as a system to manage a collection of information non-sequentially by linked nodes in a network form. In addition, hypertext has the following four internal functions.

(1) *Browsing*: visual display of network structure.
(2) *Navigation*: moving around among nodes being guided by links.
(3) *Search*: information retrieval.
(4) *Authoring*: creating new nodes and links, or modifying and eliminating them.

In general, if the system incorporates graphic, audio, video, and animated information, or a combination of any of these into nodes as well as text, then it is called "hypermedia", but the principles remain the same. Actually, hypermedia is just an extension of hypertext.

2. 2 The Earliest Vision of the Hypertext

The actual term "hypertext" was coined by Ted Nelson during the 1960's as one of the new media. Nelson attributes the underlying concepts to Vannevar Bush, who presented the idea in the well-known article, "As We May Think" on "memex" [01]. Bush points out that "the human mind operates by association", and describes "the memex as a sort of mechanized private file and library". A memex is concretely explained as follows in the article.

A memex is a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory.

That is, the memex device would support a selection of information by association rather than by indexing. Memex, unfortunately, was never implemented. However, a number of experimental hypertext systems have been developed on the basis of Bush's vision.

The first researcher influenced by Bush's concepts of associative links was Douglas Engelbart at Stanford Research Institute. His idea developed into the NLS (oN Line System) and later the Augment system. NLS emphasizes three aspects: a database of nonlinear text, view filters which selected information from this database, and views which structured the display of this information for the terminal. The availability of workstations with high resolution displays has shifted the emphasis to more graphical depictions of nodes, links, and networks, such as using one window for each node [02]. Thus, Engelbart presented the first operational hypertext system.

Ted Nelson named his hypertext system "Xanadu" and extended the idea of both Bush and Engelbart. The Xanadu hypertext system is intended to store a body of writings as an interconnected whole with linkages, and to provide instantaneous access to any writing within that body. In addition, Nelson describes his system's feature as follows. [07]

We have created this system intending to offer a viable alternative to all forms of reading, writing, archiving and study now handled by methods of paper. Through the system it is possible to mimic, perhaps viably, many aspects of the great society of paper: books, magazines, private notes, copyright, royalty, archiving, and roles for author, publisher and critic.

Nelson has been trying to integrate the entire library collections of the world into seamless electronic system.

Thus, the earliest vision of the hypertext by Bush, Engelbart and Nelson was focused on a large on-line library.

2 . 3 Application Areas of the Current Hypertext System

The earliest visions of hypertext have provided the conceptual foundation for developments of current hypertext. Hypertext ideas today are applied to a wide variety of areas. Conklin, for example, has classified the application areas of hypertext into four broad categories, namely, macro literary systems such as NLS or Xanadu, problem exploration tools, browsing systems, and general hypertext technology such as NoteCard [08] or Intermedia [03] whose primary purpose lies in the experimentation with hypertext itself [02].

Here, CD-ROM Encyclopaedia and the information retrieval system applied to it seem to be helpful in attempting to introduce the current application areas of the hypertext.

2 . 3 . 1 CD-ROM Encyclopaedia

Today, although many people are paying so much attention to multimedia technology, the core concept of multimedia can be found in the hypertext system. CD-ROM Encyclopedias are especially booming now. Its reference capacities are easy and convenient to use. For example, Bookshelf '94 by Microsoft consists of one disc which includes seven popular reference books: The American Heritage Dictionary, The Original Roget's Thesaurus, The Columbia Dictionary of Quotations, The Concise Columbia Encyclopaedia, Hammond Intermediate World Atlas, The People's Chronology, The World Almanac and Book of Facts 1994. [09]

Bookshelf '94 provides cross-referenced information including not only text but also animation, video and sound. The user can select which book(s) to look in according to the subjects or his or her interest. That is, he or she can search for topics in all seven reference books at once or in any subset. In addition, the user can move more rapidly from article to article or book to book by utilizing links.

On the other hand, from my experience in using some of the CD-ROM Encyclopaedia, they have limited access points and provide few ways of searching adequate words which should form the sought concepts. That is to say, the method of search is solely dependent on each word which does not guarantee to represent the content of any potion of the encyclopaedia. In other words, each word in the text of the encyclopaedia is indexed by some arbitrary method such as alphabetical order rather than their semantic content. This leads the user to question how a node is linked to the other node. As the result, the user can easily become disoriented in the network.

In addition to this, it is impossible for the user to add or change the nodes and links except adding simple notes to the nodes. Every node and link, so to speak, is decided by the designer. In short, the above mentioned means the CD-ROMs are just read only or considered to be passive media. This is a disadvantage of CD-ROM systems, but on the other hand, this is the most important fundamental characteristics because content structure can not be altered.

2.3.2 Information Retrieval

The idea of hypertext is applied to the field of information retrieval systems in order to cope with the problems of information retrieval systems. Although most information retrieval systems employ the Boolean search strategy, there is no disagreement that there are some problems in Boolean searches. Cooper describes, for example, that "the well-known drawbacks of the Boolean design include an inhospitable request formalism, frequent null output and output overload, and lack of provision for differing emphasis on different facets of the search" [10].

The major difference between hypertext system and the information retrieval system is as follows: In contrast to the information retrieval systems such as traditional library retrieval system rely upon query formulated with the application of Boolean logic (AND, OR, NOT), information retrieval method of the hypertext system is dependent on the network as hierarchical (organized links) and non-hierachical (referential links). In other words, hypertext system emphasizes the navigational method (following links) or graphical browsing than indexing (keyword link) and access to information is accomplished by navigating and browsing through links in the network instead of queries. In the hypertext system, it is possible to create links not only between documents and index terms but also within a set of documents. In addition, the hypertext system enables the user to get access to the specific information of which the user may make direct requests.

Thus, the application of the idea of hypertext to the information retrieval system brings about new possibilities to access to information. However, Lancaster and Warner suggest, "the solutions to the problems with current hypertext are either to allow the readers to create links at the time of use or to endow the system with enough intelligence to program its own links" [11]. In short, the information retrieval system based on the hypertext is expected to realize and provide capable inference mechanisms to satisfy the user's needs of many kinds. However, some problems of the current hypertext system that the user encounter exist and they are described in the next section.

3. Problems of the Current Hypertext System

Hypertext offers a very powerful way of organizing and accessing to information by nodes and links. However, experiences in using hypertext systems have revealed some problems for the user, such as getting lost in following obscure links in the network, or having trouble in selecting the most pertinent link or cognitive task scheduling. In addition, hypertext is not as portable as a book and its screen is not so easy to read.

To borrow Conklin's phrase, the essential problems of hypertext can be expressed as following: [02]

(1) *Disorientation*: the tendency to lose one's sense of location and direction in a non-linear document.

(2) *Cognitive overhead*: the additional effort and concentration necessary to maintain several tasks or trails at one time.

3.1 Disorientation

In the case of reading printed text such as books, an author will guide the reader by the sequential structure of what is written. On the other hand, with hypertext, the user has to guide himself or herself by association or inference.

Disorientation is the problem of not knowing where the user is in the hypertext network and how to get to another node that the user knows its existence somewhere in the network. The hypertext system can not help guide the user to the relevant node. This means that the user gets lost in the hypertext network.

Based on my experience of using Bookshelf '94, as a simple example of the hypertext system, let us consider the following case when a user wants to investigate what classes exist in vertebrate and to search the term "vertebrate". Figure 2 illustrates some of the possible nodes and transitions (links) from VERTEBRATE.

In Figure 2, although there are various routes (trajectories) which the user would select, let us consider the following two possible transitions. A word in italics refers to the name of each node.

(a) *VERTEBRATE→BIRDS→CHICKEN*

(b) *VERTEBRATE→BIRDS→TURKEY→CONQUISTADORS→PIZARRO→PERU→ANDES→ACONCAGUA*

In the case of (a), the user can understand easily the relation between each node because the relation is very simple: *BIRD* is one of the five classes of *VERTEBRATE*; *CHICKEN*

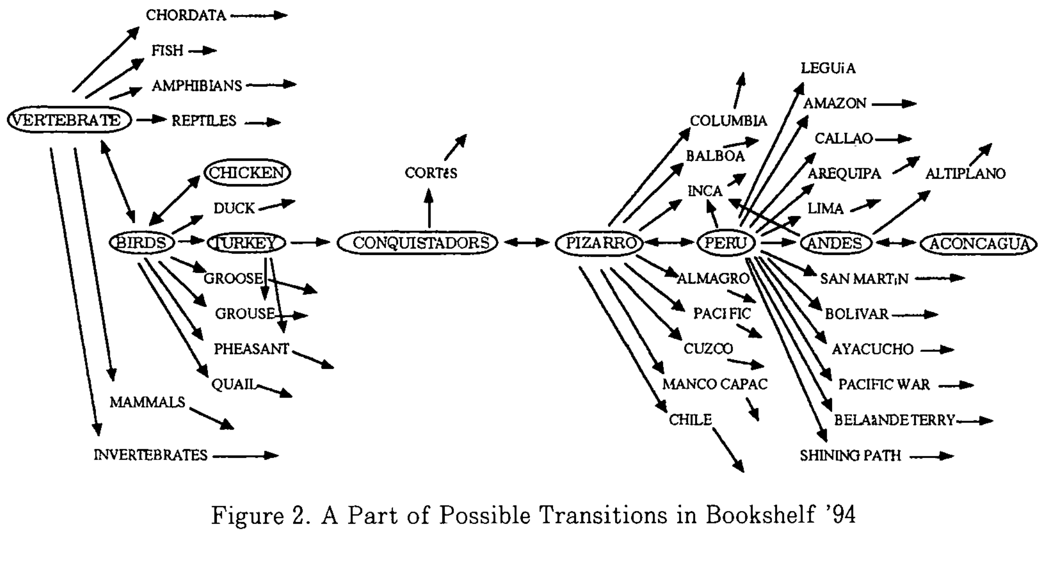

Figure 2. A Part of Possible Transitions in Bookshelf '94

is a chief domestic *BIRD*. That is, the relation can be represented as "is a kind of". In addition, the user has no choice except getting back to *BIRD* because *CHICKEN* has only one link to *BIRD*.

On the other hand, in the case that a user has navigated (b) according to his or her interests, when the user reaches the final node (*ACONCAGUA*) he or she may be not able to understand why he or she has arrived *ACONCAGUA* from *VERTEBRATE* and may be at a loss. Because the relations between each node are unquestionably complicated for the user. According to The Concise Columbia Encyclopaedia of Bookshelf '94, the relations can be expressed as follows:

- *TURKEY→CONQUISTADORS*
  The domestic turkey is descended from the Mexican turkey, taken to Europe by Conquistadors.

- *CONQUISTADORS→PIZARRO*
  Pizarro was one of the greatest Conquistadors.

- *PIZARRO→PERU*
  Pizarro was a conqueror of Peru.

- *PERU→ANDES*
  A central region, with 60% of the population, consists of three ranges of the Andes mountains.

- *ANDES→ACONCAGUA*
  The Andes mountains reach a high point of 22,835 feet at Aconcagua.

In the navigation process, according to the above example, it may be difficult to remember all of the relations from starting node to the final node. The key point is the referential connection between *TURKEY* and *CONQUISTADOR* because all other connections can be regarded as hierarchical relation. It is important to connect *TURKEY* to *CONQUISTADORS* because the user is able to know how the domestic turkey was introduced to Europe. However, whether the connection is meaningful or meaningless for the user depends on the purpose for which the user searched the term "vertebrate". Unfortunately, the current hypertext systems can not make that decision because they do not provide the choices to meet the user's purpose.

Thus, the disorientation problem is found in the difficulty for the user to select the most pertinent link or to decide whether a link is meaningful or meaningless for the current work to be done. In the process of navigation and searching, the current hypertext system does not have a function to diagnose the data to be processed in the next step by the inference mechanism as humans possess. That is, the current hypertext system does not have the inference functions to help the user select the most pertinent link. As one promising method in order to cope with this problem, *information filtering* has been proposed.

Information filtering is used to help the user select the most suitable links when a situation arises in which too many links are available for the user. The system should store a user profile with information such as areas in which the user is or is not interested within the chosen subjects and a history of explored links by the user. The system would then match the profile against the attributes of available links. As the result, eliminating uninterested links may reduce the number of choices of links. In this meaning, information filtering can be regarded as a kind of inference on the basis of some information to work as the rule in the process of navigation. Unfortunately, information filtering has not been implemented yet.

The other solution to this problem lies in the improvement of user interface, such as the following three methods. The first solution is to show the user all of the connections between nodes (links). The system shows the user how the nodes are linked together by arranging the available nodes for them in a graphical browser including both a local view of the network and a zoomed-in view of the current area. According to the graphical browser, the user can select the most suitable links. That is, graphical browser can be used as the tool with reference pointer function which enables the user to inspect the content in the node (See figure 3.). The second solution is to take the lost user back to where he or she started. The third solution is to present an on-call search history, showing where the user has already been and the path ways he or she has followed.

Using the above solutions, most of this problem can be solved. However, in the large hypertext network such as Bookshelf '94, it may be impossible to show every connection or relation by a graphical browser. As the result, the user can still be at a loss.

I would say that if we depend on the individual word, which is separated from textual context to establish links in the hypertext system it will probably provide some mere clues to be used for retrieving information, which does not satisfy the conditions presented in thinking mode of humans. In other words, in establishing links in the hypertext system, the most important issue is how to secure semantic proximity of the linked nodes. In addition to this, not only the relations between neighbouring linked nodes but also the relations between clusters of nodes are of great significance.

3. 2 Cognitive Overhead

Cognitive overhead is a more serious hypertext

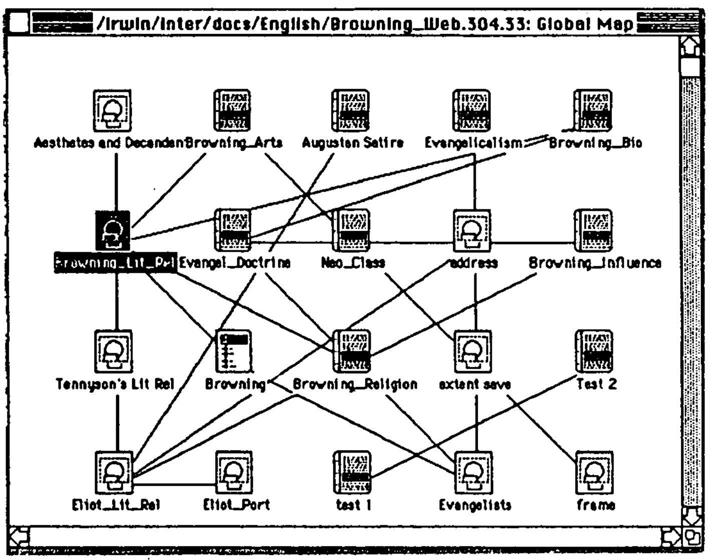

Figure 3. A Sample of Graphical Browser (A global map showing all of the links available in the system. This map pertains to the English author, Robert Browing.) [03]

problem which seems to be related to the human information processing ability. It occurs mainly in the process of authoring.

This problem is the difficulty to become accustomed to the additional mental overhead required to create the name, and keep track of links [02]. It relates to defining and creating nodes and links in the hypertext network. Question now arises as to how to define a model of the nodes and links. In general, there are three main methods of the how to create links as follows:

(1) *explicit authoring of links*
The actual links are defined and created by the author at the time the hypertext system is implemented in the computer.

(2) *user dependent creation of links*
The hypertext system allows the user to create new links at the time of use of the system.

(3) *inferential construction of links*
The system constructs links on the basis of inference.

The hypertext system of only explicit authoring of links is static in nature. In this case, it is quite difficult for the author to define what is most appropriate access point for each user and decide how to link these points, because each user is unique and has different desire. That is, any relations between nodes that the author could not anticipate at the time the system was implemented would not be available for the user.

Many hypertext systems adopt both explicit authoring and user dependent creation of links in order to cope with the above problem and to enable the user to build a personal knowledge structure. Although the user dependent creation of links may be very important, it will cause some new cognitive problems at the same time. Because it is quite difficult for the user to represent the ambiguous idea as a node and to remember its content, names of the new nodes or links which the user has created. In addition, frequent changes will be resulted in the disorderly or confusing hypertext network structure.

Furthermore, the number of links which the author has to chose and decide is may be too many, especially in large and complex hypertext system. The one solution to this problem is "the inferential construction of links" which endows the system to construct links on the basis of association like humans do, on the assumption that such associative function is materialized.

3.3 The Major Causes of the Problems

It follows from what has been said above that the essential problem of the hypertext seems to be caused by the following:

(1) the limitation of human memory capacity.

(2) the mixed condition of linkages, namely referential and hierarchical.

(3) the lack of inference function.

3.3.1 The Limitation of Human Memory Capacity

Most theories of human memory suggest that human memory consists of two components, *short-term memory* and *long-term memory,* and that the capacity of short-term memory which holds information in the temporarily activated state seems to be limited in amount and time. According to Rumelhart, the limitation of short-term memory capacity is to be of two sorts. [12] One is the number of items which humans can retain in the memory at any one time. The other is the temporal limitation of this. In addition, of course, there is the interaction of these. George Miller suggested that the number of items or chunks (the unit of information) humans can remember at one time in short term-memory for immediate recall is 7 (plus or minus 2) [13]. In addition, Melton proposed that the more information in memory the faster forgetting seems to occur [14]. This helps explain the cognitive problems that the user is supposed to face.

Because of the limitation of human memory capacity, the current subject of interest which is to be activated is often subdued as the user is apt to be forced to express their ambiguous idea at that time in a set of words as a node in the process of authoring, and at the same time to be forced to remember the reason why he or she arrived at a current node (for example, *Vertebrate→Aconcagua*) in the process of navigation. This will divert the user's attention from the real work to be carried out and this leads to the cognitive overhead.

3.3.2 Mixed Condition of Linkages

In the current hypertext system, the user can either traverse the hierarchy or search referentially. For example, the relationship between *Vertebrate→Bird→Turkey* in Figure 2 can be understood as a hierarchical one. In contrast, the relationship between *Turkey→Conquistador* is a referential relationship instead of hierarchical one.

Thus, the hypertext system must have a mixed condition of hierarchical links and referential links because making the relationship between *Turkey* and *Conquistador* is done by reference using human associative function. On the other hand, a referential condition refers to a change of topic to another cluster. As a result, this leads to the disorientation problem.

3.3.3 The Lack of Inference Function

Humans can solve problems on the basis of their own experiences that are already stored in the brain. Experiences are stored in the long-term memory which can be traced through subsequent retrieval or recall. It is used not only to solve immediate problems but also to acquire new knowledge at the same time. This process, namely, to come to new knowledge based on a set of rules to acquire the past knowledge, is called "inference". In other words, by using inference humans are able to increase ideas much more than they have learned.

In implementing the inference mechanism in the computer, a great deal of effort has been made on the realization of human knowledge representation in the artificial intelligence. One of the successful example is MYCIN as an expert system. The MYCIN system was developed originally to provide consultative advice on diagnosis of and therapy for infectious diseases – in particular, bacterial infections in the blood [15]. MYCIN is rule-based, consisting of hierarchical networks of IF-THEN rules based on propositional logic.

Although the goal of hypertext may be different from artificial intelligence systems, the expert systems such as MYCIN provide valuable suggestions for the user to make decisions and solve problems. In contrast, the hypertext system is not intended for acquiring derivative knowledge such as conclusions, or diagnosis to solve a problem. It is intended for accessing to information more actively and for building the user's own knowledge structure.

To cope with the essential problems of current hypertext system, inference function as well as human memory faculty are strongly desired to be implemented in the navigation process as an internal operation. In addition, in the process of authoring, the best method is to enable the system to create its own links by inference or association mechanisms to meet the user's demands. In other words, the links of hypertext must be established according to human association, which seems to depend largely on the memory structure.

4. Hierarchical Semantic Network

To understand and solve the essential problems of hypertext, we need to examine the human memory structure. In this section I try to discuss the features of the human long-term memory structure and to propose a simple model of describing semantic relations between nodes on the basis of hierarchical semantic memory.

4.1 Semantic Memory

According to Tulving, the information stored in the long-term memory of humans can be categorized into two types: *episodic memory* and *semantic memory* [16].

Episodic memory receives and stores information about temporally dated episodes or events, and temporal-spatial relations among these events. That is, it refers to memory of personal experiences and their temporal relationship. This can be explained in more detail. Humans can retain a large number of concepts and categories together with relationships among them all of which seem to be organized in long-term memory in some form in order to comprehend a new situation in the world. In this context, it may be not meaningless to examine the issue related to concept.

According to Seishin's Dictionary of Psychology, concept is defined as follows: [17]

Concept is created by thinking or judgment. It is a general idea which is clearly defined.

Although the discussion on concept is extensive in scope and deep in analysis, I should like to limit it to the notion of class concept. Because the class concept involves both the unique and particular relations shared among the members of the class, and the mutual and relative relations between classes which include the hierarchical and the family relations. This approach is related to what is described below, particularly the hierarchical-semantic memory.

The most popular method to represent the relationship between various concepts in long-term memory is to employ the semantic memory structure. The earliest idea of it was introduced by Ross Quillian [18]. It is designed as a network model of human associative memory. That is, its model is based on associations among knowledge units. The main idea behind the semantic network is

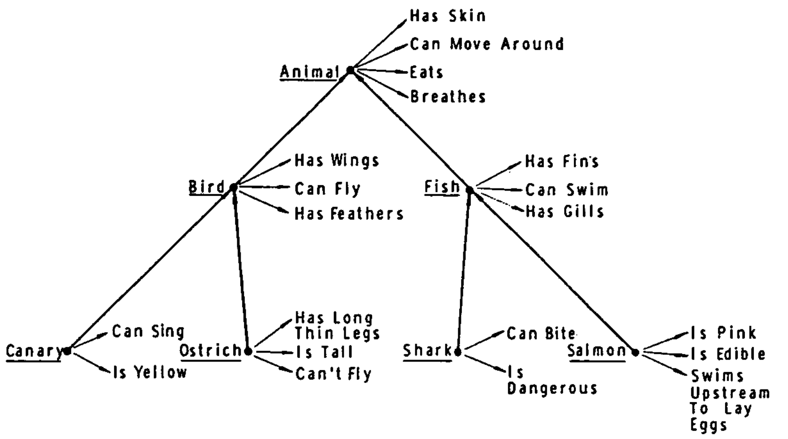

Figure. 4. Illustration of the hypothetical memory structure for 3-level hierarchy. [18]

that the meaning of a concept derives from the ways in which it is connected to other concepts. Concepts are organized by both the semantic and the hierarchical structure in human memory.

Figure 4 illustrates the well-known sample of organization of hierarchical-semantic memory structure.

It is not an easy task to define the "meaning" of meaning and there has been endless debate on it, but I should like to restrict it to the problem of denotation, or denotatum as follows.

Words have the function of indicating some object or image. I could say that the object or image in this context is the meaning of a word and the meaning of each word is represented in relation to other words. That is, in the memory, each word is stored with it a configuration of pointers to other words and the configuration represents the relations of the meaning of the words. For example, ISA (is a kind of) means to indicate membership of a category. The relationship between "bird" and "animal" can be represented as "bird ISA animal". This means that a bird is a kind of animal, being animal the superset of bird. On the other hand, HAS such as "HAS wings" is used to describe the properties of the node. Thus, semantic memory consists of *"superset"* or *"subset"*, and *"properties"*.

The important point of semantic memory is that particular information of a node such as "canary can fly" need not be stored in the canary node, because the fact that canary can fly can be inferred by retrieving "canary", which is a kind of bird that can fly. In short, the key point is that the system based on semantic memory enables to make inference by *"property inheritance"*.

Collins and Quillian attempted to test the following assumption in order to prove the semantic hierarchical memory structure [18].

Then to decide "A canary can sing," the person need only start at the node canary and retrieve the properties stored there to find the statement is true. But, to decide that "A canary can fly," the person must move up one level to bird before he can retrieve the property about flying. Therefore, the person should require more time to decide that " A canary can fly" than he does to decide that "A canary can sing".

They have made the following three assumptions: The first assumption is that both retrieving a property from a node and moving up a level in a hierarchy takes time. The second one is that the times for these two processes are additive whenever one step is dependent on completion of another step. The third assumption is that the time to retrieve a property from a node is independent of the level of the node, although different properties may take different times to retrieve from the same node.

In their experimental test to examine above assumptions, subjects were given a series of true-false questions such as "A canary is a bird" or "A canary is a fish" and were required to answer as quickly as possible. The subjects would each rest their fingers on response buttons (one for true, the other for false) and a sentence was displayed on a video display. Figure 5 shows the response times required to answer questions as a function of their distance in the proposed hierarchy.

In Figure 5, P sentences such as P0, P1 or P2 indicate sentences that state property relations, while S sentences such as S0, S1 or S2 indicate sentences that state superset relations. As shown in Figure 5, the more links a subject has to traverse to answer the questions, the longer the response time. Although these data support their assumption, Rumelhart points out the following: [12]

It is thus clear that although logically category membership is all or none, psychologically things can be more or less members of a conceptual category. It appears that judgment of category membership depends not so much on a fact represented directly in the structure of memory, but on a process which somehow determines class membership through a consideration of the similarities of the typical instance of the subject concept to the definition of the category .

To summarize, I would say that semantic memory is very promising to represent the structure and ·nature of the relationship

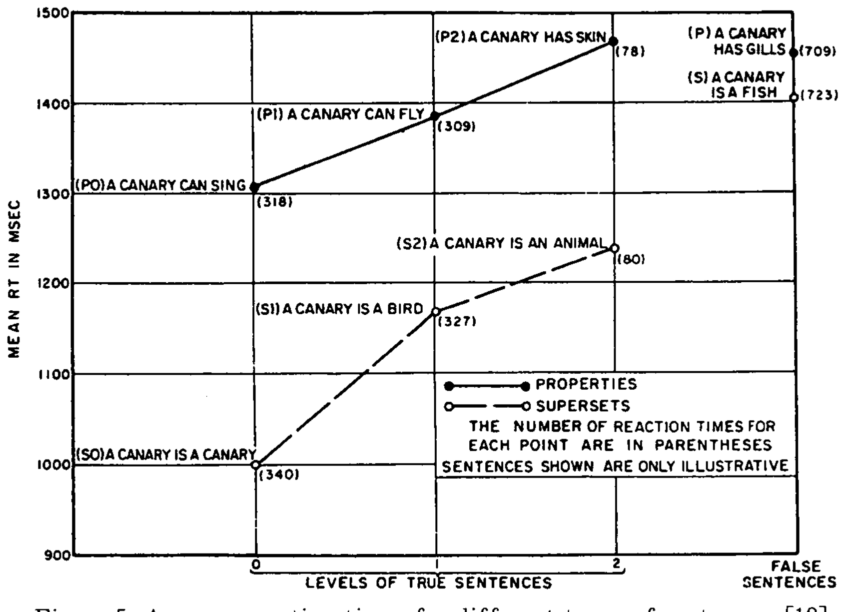

Figure 5. Average reaction times for different types of sentences. [18]

between various concepts in the nodes stored in the hypertext system because it allows the user to understand the relations between nodes of the hypertext system as hierarchical semantic relation.

4.2 Hierarchical Semantic Relational Model

Julius Tou describes that "in an elementary concept we may represent knowledge by structure and information", and proposes following formula: [19]

Structure + Information → Knowledge

It may not be wrong to say that this means that information is not the same as knowledge, and knowledge is structurally organized information. This leads to questions like "How do humans construct information in the memory?" The first step in representing human knowledge is to describe how information is represented in the human long-term memory.

In general, "representation (in semantic network) is a set of conventions about how to describe a class of things" [20] and classification is one of the basic ways of organizing information. The most fundamental activity of human mind can be considered a classification which is the act of organizing the information into some systematic order. Successful classification requires great attention to determine a set of conventions (how to make classifications that create the type which has the same feature), because it depends on what the user wants to use it for.

In Figure 6, as a simple example, I tried to illustrate a part of the classification of the animal kingdom on the basis of semantic memory which is a method to represent human

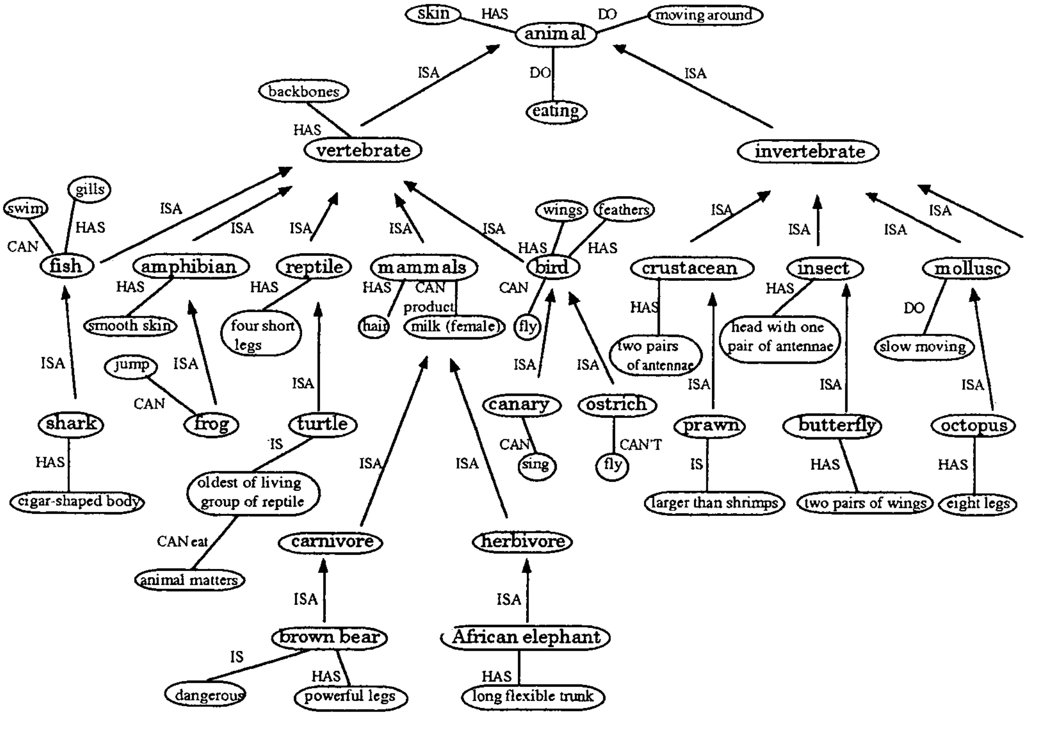

Figure. 6. A Small Segment of Classification of The Animal Kingdom

knowledge by a hierarchically structured graph in order to show how humans make use of multiple indicators, simultaneously making both hierarchical and referential linkages, between the animal and other concepts to remember the identity and description of an animal.

As I described previously, it is quite important to show the reason why nodes are linked to each other for the hypertext users. In this meaning, the relationship between nodes must be represented as simple as possible. In Figure 6, I used only the following five labels as a different kinds of links for specifying relations between linked nodes.

(1) ISA (*is a kind of*): define membership of a set.

Bird ISA vertebrate.

(2) HAS: define property to be expressed by object.

Bird HAS wings.

(3) IS: define property as characteristics.

Brown bear IS dangerous.

(4) DO: define normal actions.

Animals DO eating.

(5) CAN: define special actions.

Carnivore CAN eat animal matters.

In this model, CAN'T must be added to the CAN indicator because some exceptions such as *Ostrich can not fly* exist. In case of an exception, the subordinate property must take precedence. In short, "*Ostrich can not fly*" must take precedence over "*Bird can fly*".

The important feature of hierarchical semantic relational model is that it enables to make inference. In semantic network, a mechanism of "*property inheritance*" in which each node at a lower level inherits the properties of the elements at a higher level can be used to make inference. That is, through this mechanism, it is possible not only to save storage space of a computer memory but also to organize information in a way that allows inference.

5. Problems to be Discussed

In Figure 6, the five labels, ISA, HAS, IS, DO, CAN can be understood as "*indicators*" which define and classify the attribute(s) or property of a member of animal kingdom. Hypertext system based on hierarchical semantic relational model, to specify a certain node relation, the user can select one of ISA, HAS, IS, DO, CAN. Representation of these limited relations by graph structure is a valuable hypertext system that allows the user to see the relationships more readily within an information structure. That is, it is a promising method in a limited subject and the ability to capture the inherent meaning of the data from real world and to follow classification links can explicitly disclose the semantic structure for the user.

In contrast, it is quite difficult to apply hierarchical semantic relational model using some indicators to a large hypertext such as Bookshelf '94 because each object must be located at the systematically unique location, such as in a classification of the animal kingdom. In a sample of Figure 2, the only relationship which can be understood as hierarchical, namely a relationship which can be represented by ISA, is *Vertebrate→Birds→Turkey*. On the other hand, the relationship between *Pizarro→Conquistadors, Peru→Andes, Andes →Aconcagua* can be regarded as a pseudo hierarchical one. Much more study is needed for efficiently representing a referential and a pseudo hierarchical relationship which is generated through human inference, in addition, episodes or events including the shifting of user's interest in the process of time. I should like to continue my research in this area in order to prove that semantic network is effective in describing the relations between nodes for hypertext system.

In concluding this article, this paper is a part of my research at The University of British Columbia as a visiting scientist for the period from April 1994 to March 1995. I would like to express my especial gratitude to Dr. Robert M. Miura at the Department of Mathematics of UBC and Mr. Tsuneharu Gonnami at the Asian Library of UBC for the support and hospitality I received during my stay.

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<REFERENCES>

[01] Bush, V. As we may think. The Atlantic Monthly, July, 1945, p.101-108

[02] Conklin, J. Hypertext: An introduction and survey. Computer, 20, 1987, p.17-41

[03] Smith, K. Hypertext-linking to the future. ONLINE, Vol.12, No.2, March, 1988, p.32-40

[04] Nielsen, J. Hypertext & Hypermedia. Academic Press, INC, 1990, p.263

[05] Nelson, T. Getting it out of our System. In Information Retrieval: A Critical View. Schechter, G. Ed. Thompson Books, Washington, D.C. 1967, p.191-210

[06] Iwanami: Dictionary of Information Science. (In Japanese), Tokyo: Iwanami, 1990, p.569

[07] Nelson, T. Replacing the printed word: A complete literary system. In IFIP Proceedings. October, 1980. p.1013-1023

[08] Halasz, F. Reflections on NoteCards: Seven issues for the next generation of hypermedia Systems. Communications of the ACM, Vol.31, No.7, July, 1980, p.836-852

[09] Microsoft: Bookshelf '94 (CD-ROM Encyclopaedia). 1994

[10] Cooper, W. Getting beyond Boole. Information Processing & Management, Vol. 24, No.3, 1988 p.243-248

[11] Lancaster, F. and Warner, J. Information Retrieval Today. Information Resources Press, 1993, p.292

[12] Rumelhart, D. Human Information Processing. John Wiley & sons, 1977, p.232

[13] Miller, G. The magical number seven, plus minus two: some limits on our capacity for processing information. Psychological Review, Vol. 63, No.2, 1956, p.81-97

[14] Melton, A. Implications of short-term memory for general theory of memory. Journal of Verbal Learning and Verbal Behavior. Vol.2, 1963, p.1-21

[15] Davis, R., Buchanan, B., and Shortliffe, E. Production rules as a representation for a knowledge-based consultation program. Artificial Intelligence, 8, 1977, p.15-45

[16] Tulving, E. Episodic and Semantic Memory. In Tulving and Donaldson, W., Ed., Organization of Memory. New York Academic Press. 1972, p.381-403.

[17] Seishin: Dictionary of Psychology. (In Japanese), Tokyo: Seishin shobo, 1993, p.54

[18] Collins, A. and Quillian, M. Retrieval time from semantic memory. Journal of Verbal Learning and Verbal Behavior, Vol.8, 1969, p.240-248

[19] Tou, J. Knowledge engineering. International Journal of Computer and Information Science, Vol.9, No.4, 1980, p.275-285

[20] Winston, P. Artificial Intelligence: Third Edition. Addison-Wesley. 1992, p.16