

## SEMANTICS OF RELATIONSHIPS IN KNOWLEDGE ORGANIZATION: LATERAL RELATIONSHIPS

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Briefly overviews the occurrence and applications of semantic relationships, especially lateral relationships (non-hierarchical associative relationships), in different domains and mentions selected categorization schemes of such relationships. Presents an updated categorized list of lateral relationships.

**KEYWORDS/DESCRIPTORS:** Knowledge organization, Semantic relationships, Non-hierarchical associative relationships, Lateral relationships, Categorized list

### 1 SEMANTIC RELATIONSHIPS

#### 1.1 Recognition of Relationships among Concepts: A Cognitive Process

'Relationship' is an abstraction belonging to or characteristic of two entities or parts together (WordNet 2.1). A relationship exists between two concepts when some meaning is implied between them. Identifying and categorizing relationships, therefore, has an important role in all information processes. Information processes include a wide range of activities, such as, thinking and intellection, learning, understanding and assimilation, classification, information seeking, database searching and information retrieval, decision-making, communication, etc. All these are essentially cognitive processes. "The central point of the cognitive view is that any information processing, whether perceptual (such as perceiving an object) or symbolic (such as understanding a sentence) is mediated by a system of categories of concepts which, for the information processor constitutes a representation or a model of his world". (Mey, 1982, p.4) As Ingwersen points out "when seen from a cognitive perspective all of

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interactive communication activities in IR (information retrieval) and information seeking can result in processes of cognition which may occur in all the information processing components involved” (Ingwersen , 1996, p.11; see also Krzeszowski, 1993). - Any act of information processing, therefore, cannot be independent of the information processor’s worldview of concepts and conceptual categories. In fact the effectiveness of the information processing activity depends to a certain extent on the worldview of the processor. However, this worldview of an information processor and even the collective worldview about a concept are constantly evolving and are subject to transformation as new concepts are identified and conceptual relationships between these and the existing ones are identified.

Relationship implies the existence and role of two or more entities among which relationships occur. A user may select from among the entities and their relationship(s) for particular purposes. There may be different types of participant or semantic role – that is an “entity realized by a noun or noun phrase in a clause or sentence.” Such roles include the following (WordNet 2.1). The examples are from Hutchins (1975) categorization of case relationships:

- affected role, patient role, patient -- the semantic role of an entity that is not the agent but is directly involved in or affected by the happening denoted by the verb in the clause. Ex: The car was damaged.
- agentive role, agent -- the semantic role of the animate entity that instigates or causes the happening denoted by the verb in the clause. Ex: John painted a picture.
- benefactive role, beneficiary -- the semantic role of the intended recipient who benefits from the happening denoted by the verb in the clause. Ex: The teacher was given a book.
- instrumental role, instrument -- the semantic role of the entity (usually inanimate) that the agent uses to perform an action or start a process. Ex: The vegetable was cut by a knife.
- locative role, locative -- the semantic role of the noun phrase that designates the place of the state or action denoted by the verb. Ex: The party was held in the park.
- recipient role, recipient -- the semantic role of the animate entity that is passively involved in the happening denoted by the verb in the clause. Ex: John received the gift.

- resultant role, result -- the semantic role of the noun phrase whose referent exists only by virtue of the activity denoted by the verb in the clause. Ex: The table was repaired.
- temporal role, temporal -- the semantic role of the noun phrase that designates the time of the state or action denoted by the verb. Ex: A party was given yesterday.

Hutchins added two additional case relationships: Ablative (John gave the book) and Directional (Ice melted into water)

## **1.2 Semantic Map of Concepts**

A semantic map of concepts may be considered as an abstract representation of the collective worldview of several information processors about concepts and conceptual relationships. In other words the semantic map of a concept is a logical representation of the collective worldview of the concept and its known conceptual relationships with other concepts. This semantic map changes when a new conceptual relationships between the concept and some other concept is identified/discovered. The semantic map of a domain is, therefore, a representation – graphical or otherwise – of all the concepts occurring in or relevant to the domain and their inter-relationships. From such a viewpoint thesauri, classification schemes, ontologies, are all semantic maps. Theoretically a concept may have conceptual relationships with any other concept cutting across domains. However, from a pragmatic point of view it is both useful and necessary to identify those conceptual relationships between concepts that are strong enough to warrant recognition and have the potential to substantially contribute to enhancing information processes centered on the concept. For example, in the context of information systems such processes as query and search formulation, the search process, classification and indexing, etc and even the processes of building new semantic or association maps such as vocabulary control devices, ontologies, etc. can be significantly enhanced if the information processors have access to semantic maps representing the collective worldview of the concept. This is one of the principal advantages of tools that map concepts including thesauri, classification systems, ontologies, etc. Experience has shown that categorization of relationships into a limited number of categories is helpful in developing conceptual maps. It is an important activity in designing and querying information systems as they can contribute to meaning and understanding. In this sense a relationship is something more than being a mere connective between two

concepts. Green, Bean and Myaeng (2002) point out that “a ubiquitous and timeless human cognition activity is the ongoing effort each individual makes to construct a cohesive and predictable mental view of the world around...seeking patterns by which to organize and make sense of it. This involves conceptually clustering things and ideas into named categories based on observable shared characteristics judged salient in a given context, with the resulting categories held together by some sort of mental framework of relationships, in short, classification.”

## **2 RELATIONSHIPS AMONG CONCEPTS IN KNOWLEDGE ORGANIZATION**

Relationships among concepts are of interest in a variety of contexts. Recognition and categorization of conceptual relationships has been an area of research for a number of disciplinary groups including philosophers at least from the time of Aristotle, life scientists, and library classificationists from the time of Melvil Dewey. More recently, systems analysts, linguists, and web ontologists have been interested in identifying and mapping relationships among concepts / entities for a variety of purposes many of which overlap. The typology of LRs developed by Neelameghan and others (1974; 2001) has been cited in papers on organizing information sources on religion and spirituality (Fiorentino, 2001), in web searching (Kari and Savolainen, 2001), and in browsing image collections (Gordon, 2001). Other applications of the typology include those in systems and domain analyses especially for "hypermedia and world wide web applications which provide a high degree of linking and navigational support" (Yoo and Bieber, 2000); in relation to software engineering for web development (Catanio et al, 2002), and in lexical cohesion studies (Morris, Beghtol, and Hirst, 2003). Yoo, Bieber and others (2000) have developed a typology of semantic relationships in web applications. According to them:

“Relationships can be categorized broadly as hierarchical vs. non-hierarchical. We consider hierarchical as internal and non-hierarchical as external. Internal relationships focus upon an object itself and its characteristics or descriptions, and among different views, occurrences or transformations of one object. Internal relationships can be broken down into self-generalization/specialization, whole/part/composition, and classification/instantiation relationships. This ... agrees with classification

relationships in object-oriented analysis. External relationships can be broken down into association / dependency and comparison relationships.”

Morris *et al* write that studies on LRs are “useful especially as part of lexical cohesion studies for improving relationships types used in information retrieval thesauri, lexical resources, such as, WordNet, linguistic analysis, text analysis, text summarization, natural language processing applications, in designing user-friendly user interfaces and thus "improving information literacy skills of information system users."

Neelameghan and Satish (2004) noted the following areas of application:

- Design of classification schemes, thesauri and other vocabulary control devices
- Design and development of databases
- Development of appropriate search strategies for information retrieval in a variety of environments
  - Web browsing, web searching
  - Searching and browsing textual and image databases
- Web design and development particularly establishing the basis for creating hyperlinks in hypertexts, hypermedia, etc documents
- Systems analysis and software engineering;
- Text semantics, lexical cohesion; and
- Natural language processing

Interestingly the above mentioned domains of applications were reported in conference proceedings and periodicals devoted to different areas, such as the following:

Artificial intelligence	Memory and cognition
Text analysis, summarization	Experimental psychology
Linguistics	Learning
Computational linguistics	Hypermedia
Natural language processing	Information retrieval
Knowledge organization	System studies

Obviously, then, different categorizations of relationships among concepts are possible in the different domains. It is, therefore, useful to develop a theory of

conceptual relationships based on a generalization and logical abstraction of the prevalent ideas and practices among different disciplinary groups. As a first step this paper attempts at contributing to categorizing semantic relationships more particularly lateral relationships.

### 3 CATEGORIES OF RELATIONSHIPS

#### 3.1 Hierarchical and Non-hierarchical Relationships

There are at least two broad categories of relationships that knowledge organizers are interested in. Designers of classification schemes and subject indexing languages are interested in semantic relationships among subjects and among concepts, while cataloguers and bibliographers are interested in relationships between bibliographic items. The tools developed for knowledge organization generally recognize two primary types of relationships, namely:

- Hierarchical Relationships, variously called taxonomic, subsumptive, and 'IS A' relationships, e.g.
  - Genus-Species / Class inclusion relationships
  - Partitive Relationships / Whole-Part relationships (in so far as they apply to living systems and geographical areas)
- Non-Hierarchical Associative Relationships or Lateral Relationships (LR)

These categories are equally applicable to concepts/subjects and to bibliographical items. Some researchers recognize *Equivalence* relationships as a third type while others include it in the second type (i.e. LR). *Equivalence* relationships are, however, relationships between verbal representations of concepts and are language-dependent. The two broad categories of relationships referred to above are largely language independent. Neelameghan (2002) discusses the different ideas of hierarchy, hierarchical relationships and hierarchical arrangement.

#### 3.2 Other Applications and Contexts

Researchers in linguistics have developed a fairly detailed typology of relationships. Findings from linguistic studies, computational linguistics, and natural language processing have influenced in some measure the design, development and use of knowledge organization tools and strategies. In recent

years there is expanding and mutually beneficial interaction between researchers in knowledge organization and those in language processing and related fields. Natural language processing, for instance, is now included in courses of studies for library and information professionals.

### *3.2.1. Relationships in WordNet*

Categorization of semantic relationships in the WordNet 2.1 is as follows:

*Meronymy* – Part to Whole relationship, i.e. the semantic relationship that holds between a part and the whole.

*Holonymy* – Whole to Part relationship, that is, the semantic relationship that holds between a whole and its parts.

*Hyponymy* – Subordination relationship, i.e. the semantic relationship of being subordinate or belonging to a lower rank or class or level.

*Synonymy* – the semantic relationship that holds between two terms that can, in a given context, express the same meaning.

*Antonymy* – the semantic relationship that holds between two terms that can, in a given context, express opposite meanings.

*Troponymy* – the semantic relationship of being a manner of doing something.

*Metonymy* – substituting the name of an attribute or feature for the name of the thing itself.

Felber's *Terminology manual* (1984) gives guidelines in identifying and representing relationships among concept terms

### *3.2.2. Relationships in structures in image schemata*

About image schemata Johnson (1987) noted:

“The abstract nature of image schemata accounts for widespread applicability of a reasonably small number of relational structures.”

Johnson's list of the most important image schemata, numbering about thirty, includes the following:

Container	Balance	Compulsion
Blockage	Counterforce	Restraint
Removal	Enablement	Attraction
Mass-count	Path	Link
Center-Periphery	Cycle	Near-Far
Scale	Part-Whole	Merging
Splitting	Full-Empty	Matching
Superimposition	Iteration	Contact
Process	Empty	Object
Collection		

Despite the differences there are many similarities and, to a certain extent, even overlap in the types of relationships recognized. It would therefore be useful to attempt at a generalization of lateral relationships.

#### 4 MULTIPLICITY OR WEB OF RELATIONSHIPS

Lateral relationships used in tools for knowledge organization such as thesauri (RT relationships) are mostly between pairs of concepts. However, in a discourse or text, multiple relationships or a web of relationships need to be recognized between the concepts presented. Consider for example the relationships between Doctor and Patient: This may arise from the text: "*the Doctor is Treating with Streptomycin a Hospital Patient suffering from Tuberculosis*". Taking pairs of concepts we may get relationships such as the following:

Patient and Treatment	Tuberculosis and Treatment
Patient and Hospital	Tuberculosis and Streptomycin
Patient and Tuberculosis	
Patient and Streptomycin	
Patient and Doctor	

Doctor and Treatment	Treatment and Streptomycin
Doctor and Hospital	
Doctor and Streptomycin	
Doctor and Tuberculosis	

(See also Time-related Relationships below)



## **5 LATERAL RELATIONSHIPS (LRs)**

### **5.1 Earlier Work**

A list of some thirty types of LRs based on work done in 1974, at the Documentation Research and Training Centre, Bangalore, India, was drawn up. (Neelameghan and Ravichandra Rao, 1975; Neelameghan and Maitra, 1978). A few more types of LRs especially those applicable in cross-cultural communications were added to the earlier list (Neelameghan, 2001). These LRs were essentially intended as aids for organizing Related Terms (RT) in thesauri. It was not until much later that the original list of LRs found practical application in the construction of a substantive thesaurus (Moholt, 2001).

Given the scope for application of LRs, more particularly for analyzing and organizing information in such fields as management, administration, history, biography, law, legislation, criminal investigations, etc., a study and understanding of the nature of relationships between concepts is useful in developing:

- Association maps / thesauri / ontologies / hyperlinking, etc to provide navigational facilities between related concepts / entities, and
- Developing guidelines for sequencing ideas e.g. isolates in an array and components of a compound subject,.

### **5.2 Generation of LRs**

LRs between concepts arise, for example, from observations, actions and reactions, experiences, experiments and other interactions of a person with entities in his/her environment - the outside world, nature, physical objects, human beings, events, phenomena etc. The concepts and the relationships among them thus conceptualized may then be communicated through some medium (oral, written, image, or a combination of them). Concepts and relationships among them may also arise through intuition and direct revelation (which are trans-sensory and trans-intellectual).

It is useful to distinguish between two broad categories of lateral relationships between concepts: that arise in the course of communication / discourse.:

- Relationships that are near permanent features of the associated concepts; these are:

- Context independent relationships between concepts so associated, and
- Context-dependent temporary / ad-hoc relationships established between concepts

The exact handling of these relationships in association maps, semantic maps, thesauri, and other knowledge organizing tools, has been a subject of debate and discussion, i.e. which of these LRs should be handled by the vocabulary of the system and which by the grammar of the system. A general rule of thumb could be that all near-permanent relationships should be handled by the vocabulary. However, conceptualization of relationships between concepts and their categorization is a necessary pre-requisite for mapping a domain and providing for interlinking of concepts and navigational facilities.

It is possible that the association map centering around a concept and the type of relationships between concepts/entities as conceptualized by a person may not be co-terminus with that of another person, for example, a recipient of the communication, especially if his/her world-view experience, culture, symbolism, domain expertise, knowledge base, etc. is different from that of the communicator. However, for providing navigational facilities via association maps (e.g. in a thesaurus, classification system, and ontology), it is necessary to make decisions on the collective world-view about the concepts under consideration. Association between concepts that are juxtaposed to one another in the course of a communication is also subject to different interpretations by different persons. Nevertheless, in a specific context and at the near-seminal level of thought process in normal persons they tend to coincide in most cases. In an experiment (Raghavan and Hemalata Iyer, 1978; Hemalata Iyer, 1982) a number of strings of concept terms presented in the 'absolute syntax' sequence (rather than in the syntax of a natural language) to over a hundred persons from different linguistic, cultural and subject groups was interpreted by them in over 95 per cent cases as was intended by the researchers.

In their paper "Aligning Systems of Relationships" Green and Bean (2006) map the lateral relationships, a preliminary version of those listed in Appendix 1, to their closest correspondence in FrameNet. They state that the analysis of this alignment highlights important characteristics of each system of relationships and reveals varying degrees of compatibility between them. An updated taxonomy of lateral relationships is given in Appendix 1. The relationships are grouped into nine broad categories; and there are subgroups within these broad groups.

## 6 CONCLUDING REMARKS

An association map such as a thesaurus or scheme of classification can act as an aid for a wide variety of information processes including knowledge representation, information search and retrieval. It can directly assist the user to understand the contexts of a concept. The inclusion of semantic relationships representing the collective world view of a concept can be effectively used in creating meaningful hyperlinks and probably even in developing knowledge-based approaches to automatic query processing in information retrieval systems. In this paper an attempt has been made to formalize the basis for creating semantic networks of laterally related concepts. Lateral relationships represent a class of non-hierarchical relationships and have generally been less clearly understood than the hierarchical relationships in thesaurus construction and in their applications in information retrieval. At one extreme lateral relationships can be taken to mean a vague 'See-also' type of relationships between two entities. Even a cursory examination of the use of hyperlinks in the web appears to suggest this. Obviously such an approach can lead to uncontrolled expansion, e.g. of query terms. The disciplining of LRs to the core set of relationships identified in this paper and applying them intelligently based on the needs and requirements of a domain is important if we need to maintain acceptable levels of precision. The possibility and feasibility of using the taxonomy proposed in this paper for enriching the specification and semantics of lateral relationships in thesauri and association maps in specific domains need to be explored.

An entity may have more than one type of relationships with another entity. A relationship may be context or domain specific. One may prefer one relationship over another depending on the context. That is, the relationships or preferred relationships indication may be different in different contexts. For example, consider the Doctor-Patient relationships. The relationships can be 'two entities usually associated with each other' say, in a hospital context. Another type of relationships can be 'service provider-service recipient'. Which type of relationships is selected depends on the context of application and this choice may also be influenced by cultural factors. Thus, although the spatial relationships is ubiquitous, in a particular context another type of relationships may be preferred.

In a thesaurus the preferred RT relationships may be made specific by indicating the name/category of relationships. Example:

**Doctor** (as service provider)

**RT Patient** (as service recipient)

Perhaps more than one type of relationships may be indicated leaving it to the user to select the one preferred for the particular context. Example:

**Doctor** (as service provider)

**RT Patient** (as service recipient)

**Doctor** (association with)

**RT Patient** (associated with)

It may be noted that the 'service provider-service recipient' relationship is more generally applicable, that is, not only in the context of a hospital.

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