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A REVIEW ON SEMANTIC RELATIONSHIP BASED APPLICATIONS

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ABSTRACT

Exploitation of semantic relationship in the represented knowledge is crucial to move the system towards intelligent system. This paper brings a detailed survey about wide range of relations that has been exploited from literature to modern computational theory. The classification of the relations may be content dependent relationship, content independent relationship, foundation relations, spatial relations, temporal relations, participation relations, mereological relations, etc. The role of relations in various domains such as searching, auditing, ranking and reasoning clearly indicates the power of relationships to make the system more human like thinking. It is very complex to reason the relation between the concepts as it differs in context, semantics and properties. This paper provides a novel attempt to explore the significance of relations in reasoning and information retrieval.

KEYWORDS

Semantic Relationship, Reasoning, Ontology, Ranking, Searching

1. INTRODUCTION

In today's world, providing entire information to the user is a complicated task. Even though the expertise is available, it has many problems to attain the information as such. The information should be represented in a machine understandable format in order to furnish the complete information to the user, based on their request. Suitable representation techniques have to be used to represent the generic or domain oriented knowledge. Some of the techniques [16] used are rules, frames, semantic network, etc. Among these, semantic network represents semantic relations between the concepts. However, it explains only about the concepts and the relation between those concepts. Ontology plays a vital role in representing the complete domain knowledge. Ontology is used to explicitly specify the concepts in a domain, properties of each concept describing various features and attributes of the concepts. So, it can be used to share the common understanding of the structure of the information among the users and to enable the reuse of domain knowledge. It separates the domain knowledge from the operational knowledge.
Though, it consists of all the concepts, it is incomplete without relationship. It helps to structure the concepts in the ontology and it could be used to provide more semantics to the information. Generally, semantic relations [17] exists between the concepts are hyponym, hypernymy, holonym, meronym, antonym, synonym. In addition to these basic relations, many other semantic relations exist. It differs from one domain to another domain.

In this paper, various kinds of semantic relations, which are used in wide range of domains, have been exploited. It also discusses the approach in which the relations could be used effectively for reasoning, information retrieval and to resolve inconsistencies in ontology.

This paper is organized as follows: Section 2 describes various categories of semantic relations used in a range of domain. Section 3 discusses about how the reasoning can be achieved with the use of basic, spatial and temporal relations. The techniques which are used to effectively search, rank and audit with semantic relations are explained in section 4. Section 5 explains the implication of semantic relations in reasoning and information retrieval with various instances. Finally section 6 concludes this paper.

2. CLASSIFICATION OF SEMANTIC RELATIONS

The primary goal of today's Internet users is to retrieve relevant documents. Most of the web documents are retrieved based on the concepts. Semantics of concepts varies from one domain to another. Thus, multiple irrelevant documents could be retrieved. Number of irrelevant documents can be restricted, making use of the identified relationships. Relationships are fundamental to semantics in order to associate meaning to words, terms and entities [1].

Semantic relations are basic components of language and thought [5]. Roger and Herrmann[5] suggested the important relations like contrast, class inclusion, similar, case relations and part-whole relations. Contrast relations include antonym relation like Contradictory antonyms (e.g. alive –dead), Contrary antonyms (e.g. hot-cold), Directional (e.g. above-below) and reverse antonyms (e.g. buy-sell). Similar relations consist of the terms that overlap in denotative meaning and connotative meaning or both. It can be classified into dimensional similarity and attribute similarity. Class inclusion includes the terms whose denotative meaning subsumes other term. It can be classified based on the following properties: perceptual subordinates, functional subordinates, state subordinates, geographical subordinates, activity and action subordinates. The relations involved in prediction or attribution have been described as case, syntactic and syntagmatic relations. It includes agent –action relations, agent-instrument relation and agent-object relation. Part- whole relations are either heterogeneous parts or homogeneous parts. Heterogeneous relations include functional relations and spatial relations. Homogeneous relations include individual and group relations. Some of the relations are not distinguishable such as ingredients that cannot be separated from the whole (e.g. pizza-cheese) and units of measure (e.g. mile-foot) also combined with one another. Roger and Hermann [5] identified totally 31 semantic relations.

Sheth et al [1] classifies the complex relationships based on the Information content. They are Content independent relationships and content dependent relationships. Content dependent relationships are classified into direct content dependent and content descriptive relationships. Content descriptive relationships are used to associate entities within a domain or across multiple domains. Based on the association, it is classified into direct semantic relationships, complex transitive relationships; inter domain multi ontology relationships and semantic proximity relationship.

Gao and Zhao [2] constructed the relationships between concepts in Government ontology based on E-Government Thesaurus. It mainly contains three relationships between the terms. They are equivalent relationship, hierarchical relationship and related relationship. Generally, there are four semantic relationships defined between the concepts in ontology. It includes kind-of relationship, part-of relationship, instance-of relationship and attribute-of relationship.

They classified Government ontology into 15 groups. They are Genus-species, part-of, population-individual, superior- subordination , synonymy, antonym, similarity, causal, agent, application relation, contradiction, timing, spatial, instance-of and attribute relations.

Database management systems also captures the semantics of an application for which database is developed. Relational database management system is widely used to accommodate real world knowledge. Certain semantic relations are incorporated in DBMS design, commonly referred as data abstractions [6]. The widely used abstractions are inclusion, aggregation and association relations. Relation represents minimum and maximum cardinalities among the entities. In database, three different types of inclusion have been identified: class, meronymic and spatial relation. Chaffin distinguish meronymic relations based on its function, separable, homogeneous and contemporaneous. Some of the meronymic relations are component-object, feature-event, member-collection, portion- mass, phase-activity, pace-area and stuff-object. Other widely used relations are possession, attachment and attribution, synonym, antonym and case relation involving agent and actions.

Some of the relations in OBO ontology are classified into foundation relations, spatial relations, temporal relations and participation relations as defined by Barry Smith et al [3]. Spatial relations include located_in, contained-in and adjacent_to. The relations like transformation_of, derives_from and preceded_by are contained in temporal relations. Participation relation incorporates has_participant and has_agent relations.

Aghila et al adapted [4] classification of the world level entities and reasoning methodology of Indian Logic system Nyaya Shastra into the KRIL system.

SO (Sequence Ontology) uses mereological relations, temporal and spatial interval relations described by Mungal et al [5]. Mereological relations include part_of, has_part, integral_part_of and has_integral part relations. Some of the temporal relations in SO are transcribed_from, transcribed_to, processed_from,processed_to,ribosomal_transaltion_of and ribosomal_transaltion_to. The relations like contains, overlaps, adjacent_to, started_by, start, finishes,maximally_overlaps, disconnected_from and is_consecutive_sequence_of are incorporated in spatial interval relations. The various relations discussed have been listed in Table 1.

Table 1. Classification of relations based on Applications

PURPOSE	**RELATION CLASSIFICATION**	**AUTHORS**
1. Literature		
Finding similarity and diversity of the semantic relations	Contrast relation • Contradictory antonyms, Contrary antonyms, Directional, Reverse antonyms Similar relation • Dimensional similarity relation, Attribute similarity relation Class inclusion relation Case relation • agent –action relations, agent-instrument relation, agent-object relation Part- whole relation • Heterogeneous relations Functional relations, spatial relations • Homogeneous relations	Roger Chaffin and Douglas J. Herrnamm (1984) [5]

	Individual, group relations	
2.Computer Science		
Information Retrieval	Content independent relationship Content dependent relationship • Direct content dependent relationship • Content descriptive relationship Direct semantic relationship, Complex transitive relationship, Interdomain multi-ontology relationship, Semantic proximity relationship	AmitSheth, BudakArpinar, VipulKashyap (2002)[1]
Government Ontology	Genus-species relation, Part-of relation, Population and individual relation, superior- subordination, synonymy, antonym, similarity, causal, agent, application relation, contradiction, timing, spatial, instance-of and attribute relations	Gao Wen-Fei, Zhao Xin-li (2008) [2]
Database Management Systems	Inclusion (Class, Meronymic, Spatial), Possession Attachment, Attribution, Synonym, Antonym Case relation	Veda C Storey (1993)[6]
3.Biology		
Reasoning over spatial and temporal relations	Spatial relations • Located_in,Contained_in, overlap, Adjacent_to Temporal relations • Transformation_of, Derives_from, Preceded_by Participation relations • Has_participant, Has_agent	Barry Smith et al. (2005)[3]
Develop sequence ontology to provide interoperability	Mereological relations • Part_of, has_part, integral_part_of, has_integral_part Spatial interval relations • contains, overlaps, adjacent_to, started_by, start, finishes, maximally_overlaps, disconnected_from, is_consecutive_sequence_of Temporal relations • transcribed_from,transcribed_to,processed_from, processed_to,ribosomal_transaltion_of, ribosomal_transaltion_to	Christopher J.Mungall, Colin Batchelor and Karen Eilbeck (2011) [4]

Table 1 gives a clear picture of the wide range of relations that have been exploited from literature to modern computational theory. Apart from these, in knowledge engineering also the relationship plays a critical role. For example, the domain knowledge could not be complete without relations since it provides more semantics to the knowledge based systems. Apart from the discussed relations, many other relations like active, associative, causal, polysemy, paradigmatic, possession, kinship, theme, predicate, measure, certainty, etc have been proposed by many authors based on their perspective.

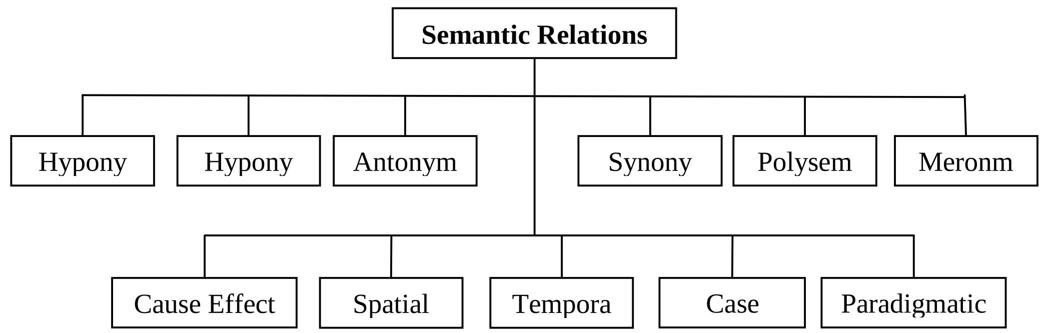

Fig 1.Generic classification of Semantic Relations

Figure 1 shows the primary classification of semantic relations. Examples of the semantic relations are given below:

Animal is a mammal (hypernym relation)
Dog is a type of mammal (hyponym relation)
Slow is opposite of fast (antonym relation)
Sick is equivalent to ill (synonym relation)
Malaria is caused by mosquito (cause effect relation)
World War I happens before World War II (temporal relation)
My house is adjacent to my uncle's house (spatial relation)
Flower is a part of Plant (meronymy relation)
Bank is an example for polysemy.
Mother and child is an example for paradigmatic relation.
Person handles machine (case relation)

The study of these relations indicates that any relations identified have to fit into any one of this category. Among these, the widely used relations are Hyponymy, Hypernym, Meronmy Cause-effect, Spatial and Temporal relations. Former four relations are commonly used in all domains. Spatial relations are widely used in Geo-spatial based applications. Temporal relations are usually used where the ordering of the events are essential.

This section dealt with the various categories of proposed relations which are used in different domains. The primary classification of semantic relations also specified in this section. Next section describes how the relation could be used in reasoning.

3. REASONING

Reasoning is the set of processes that enable the user to infer the new information based on the given set of facts. A System can mimic a human if it could infer the information automatically or semi automatically. But it requires the complete knowledge of a domain which should be represented in a well-defined manner. Many representation techniques have been used, but Description Logic (DL) provides well defined expressiveness [19] for reasoning. The development of Ontology adopts DL. The main concern of knowledge engineering is the construction of Ontologies, which consists of set of concepts, its properties and relationship between those concepts. The relationship between the concepts holds the following logical properties: transitive/intransitive, symmetry/asymmetry, reflexive/ irreflexive and functional/inverse functional. The semantic relations will hold atleast one of the property or combination of some properties. Researchers developed many reasoning algorithms which focus mainly on concepts. Few researchers developed the reasoning techniques which infer information based on the semantics of the relations and its properties [4-10]. Mainly they focus on class inclusion, spatial and temporal relations based reasoning. Automatic reasoning performs well for the relations which hold transitive properties.

Goodwin and Johnson discussed about spatial and temporal relations [8]. Semantics of the relations based on properties is not completely feasible. In this paper, the spatial relations identified are in the same as, beyond, not beyond, next in line to, directly on top of, nearest to, next to, on the right of, at. It holds the logical properties such as transitive, intransitive, nontransitive, symmetry, asymmetry, non-symmetric. As mentioned earlier, the properties of the relations play a key role in knowledge inference. Lack of these logical properties does not imply that a relation yields no inferences. But it differs based on the context. Authors have mentioned about the temporal relation Happens – Before which satisfies the transitive property leading to achieve correct and simple reasoning. Table 2 shows some of the relations [8] and its corresponding inferences.

Table 2. Relations, its properties and its Inferences[8]

Relations (R)	Properties	Inference
In the same place as	Transitive	a R b, b R c -> a R c
Next in line to	Intransitive	a R b, b R c -> ¬(a R c)
Next to	Nontransitive	a R b, b R c -> No Conclusion
Next to	Symmetric	a R b -> b R a
Taller than	Asymmetric	a R b -> ¬(b R a)
In the same place as	Reflexive	a R a
Next to	Irreflexive	a R ¬ a
Happens before	Transitive	a R b, b R c -> a R c
Taller than	Transitive	a R b, b R c -> a R c

Manual and Carlos [9] conducted two experiments which were designed to contrast opposite predictions of the model theory of reasoning and the formal rules of inference theories. In this experiments, they have used the relations like higher than, in front of, to the right of, to the left of, more than and less than. Many researches concentrate on spatial and temporal reasoning. Most of the spatial and temporal relations satisfy transitive properties and it enables the system to infer the new relations easily.

Gene ontology [10] contains many concepts and relations between those concepts. It may have one child or more than one child or more than one parent or multiple relationships exist between them. In this ontology, reasoning can be performed over is-a, part-of and regulates relations which is shown in Table 3.

Table 3. Relations, its properties and its Inferences[10]

Relation (R1)	Relation (R2)	Inference
Is-a	Is-a	a R1 b, b R2 c -> a R1/R2 c
Is-a	Part-of	a R1 b, b R2 c -> a R2 c
Is-a	regulates	a R1 b, b R2 c -> a R2 c
Part-of	Is-a	a R1 b, b R2 c -> a R1 c
Part-of	regulates	a R1 b, b R2 c -> a R2 c

Part-of	Part-of	a R1 b, b R2 c -> a R1/R2 c
regulates	Is-a	a R1 b, b R2 c -> a R1 c
regulates	Part-of	a R1 b, b R2 c -> a R1 c
regulates	regulates	a R1 b, b R2 c -> a R1/R2 c

Foundational relations between individuals, Universals and Collections have been provided in [16] by Bittner et al. They have considered individuals as parts, universals as instances and collections as members. Based on it, they have identified the relations that are mentioned in Table 4.

Table 4. Relations between Individuals, Universal and Collections[16]

Term1	Term2	Relation
Individual	Individual	part-of
Individual	Universal	Instance-of
Individual	Collection	Member-of
Universal	Universal	hypernymy
Collection	Individual	Partition-of
Collection	Universal	Extension-of
Collection	Collection	Inclusion

It has been noted that reasoning can be carried out in a well-defined manner in case if the relation holds transitive property and sometimes with reflexive and symmetry properties. It is complex in case of other relation properties. Hence, the system is required to discover the semantic relations between concepts even it persists other properties such as intransitive, irreflexive and antisymmetric properties. More illustrations are given in section 5.

This section dealt about how the reasoning could be achieved with relations. It also depicted the essence of properties of the relations for reasoning. Next section describes how the relations play a crucial role in information retrieval and auditing.

4. RELATIONS IN INFORMATION RETRIEVAL AND AUDITING

Information retrieval is processes of retrieving information from the collection of resources. Based on the user query, it searches the relevant documents and retrieves it. The ontology based semantic information retrieval system is shown in figure 2.The relevant documents are ranked according to the degree of relevance using some page rank algorithms. This section explains how the relations play a vital role in searching, ranking and auditing.

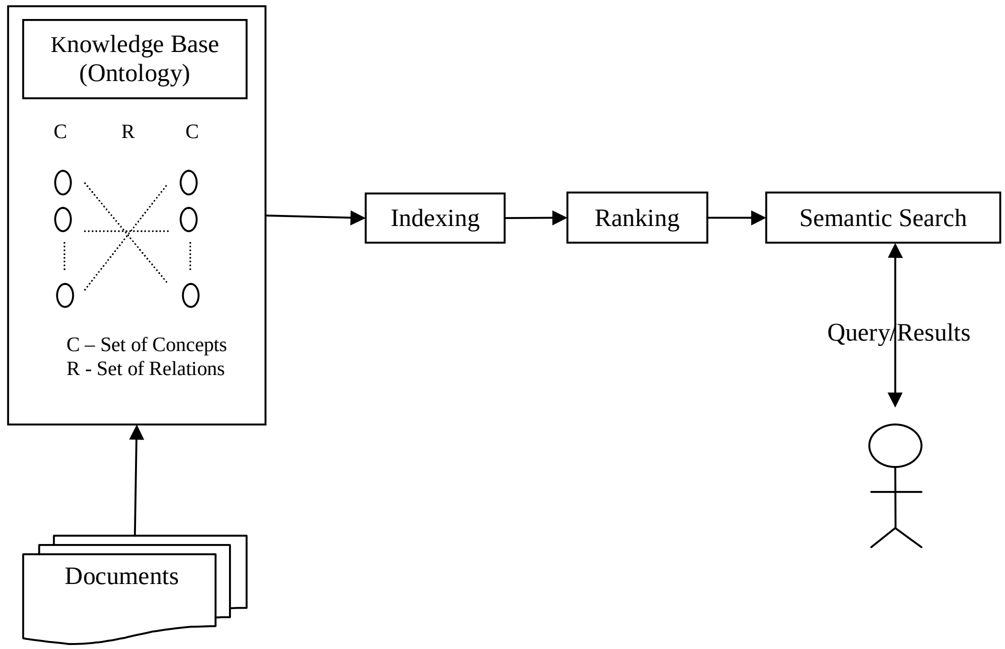

Fig 2. Ontology Based Semantic Information Retrieval System

4.1 Searching

Keyword based searching and ranking is common in information retrieval systems. Search engine retrieves information based on the user query. User requires more accurate information which could be achieved with the use of ontology based semantic search. Kunmei et al [15] proposed a system called Smartch which is used to search the concepts and rank the documents. Smartch provides four types of search such as basic search, concept search, user defined concept search and association relationship search.

Basic search provides the pages which contains given keyword(s) and its corresponding synonyms. Concept search retrieves all the instances which belong to the given concepts. In the user defined concept search, the user can select their query based on the ontology search selection method. In association relationship search, the defined association relationships have been retrieved and presented.

Generally when the user wants to search the document, they use either and/or relations. It shows the documents that contain given keywords. For example, the query given to the any one of the search engine as “List items that contains Methanol”. It retrieves many irrelevant documents which are shown in Figure 3.Clearly, it shows that the significance of semantic relations in information retrieval.

Hence a system is required to search the documents based on the semantic relations. It will help the user to retrieve the relevant documents quickly. An illustration is given in section 5 to emphasize the importance of relations in search using ontology.

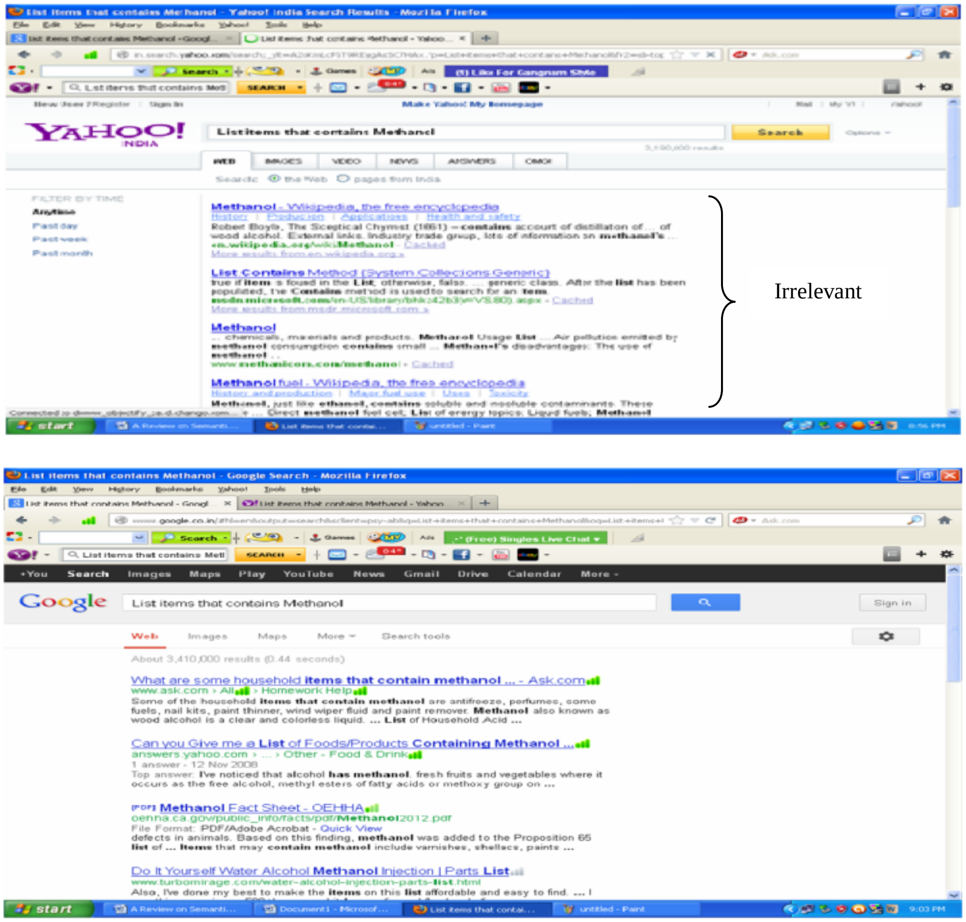

Fig 3. Irrelevant Documents retrieved from Google[20] and Yahoo[21]

4.2 Ranking

Search Engine searches the documents in the web and displays the related web pages after ranking. Ranking is accomplished based on the number of occurrences of a given keyword in the documents. A key notation of process relationship between the entities is the concepts of semantic association, which are different sequences of relationships that interconnect two entities. Semantic association existing between the entities may be either semantically connected or semantically similar [12]. Many possibilities like shortest path, longest path and least frequently occurring paths have been used to rank semantic association results. It focuses on customizability and flexibility. It ranks the documents based on the evaluation of how much the information has been conveyed to the user and how much information the user has gained.

Aleman-Meza et al [11] proposed a method called SemRank which uses relevance measure to rank the documents. This paper addresses the problem of how to exploit semantic relationships of named entities to improve the relevance in search and ranking the documents.

Kunmei et al [15] proposed a system called Smartch which is also used to rank the documents. Ranking is based on domain relevance, length relevance and frequency relevance measures. In basic search, ranking uses tf/idf method. But, in concept search and user defined concept search methods, ranking is performed over the number of instances retrieved in a given concept. For association relationship search, the measures like domain relevance, length relevance and frequency relevance have been used.

4.3 Auditing

It is a part on ontology development lifecycle. Many techniques have been used to identify classification errors, redundant and circular hierarchical relationships. Gu et al[13] audits four relationship types of FMA such as sub class, part_of, branch_of and tributary_of. All the relationship types hold transitive property. It is used to identify the kinds of potential incorrect assignments are present in the implementation of FMA relationships. They have identified the following incorrect relationship assignments: circular, mutually exclusive, redundant, inconsistent and missed entries. In this process, they have identified number of error occurred in each relationship assignments.

This section showed how the semantic relationship plays a critical role in reasoning, information retrieval and auditing. Next section shows several illustrations to understand the significance of relations and information retrieval.

5. ILLUSTRATIONS

Reasoning process involve the deduction of relations among a set of concepts from known relations of the concepts with other concepts. Semantic relations holds between the concepts are either dyadic or triadic relations. It has various logical properties, which provide valid inferences. The following scenarios depict only the dyadic relations.

Scenario 1:

Consider the statements given below:

A is a sister of B

B is a sister of C

In this example, *sister of* relation satisfies transitive and reflexive properties.

Query:*What is the relation between A and C?*

A system can easily derive the relation between A and C i.e

Inference :*A is a sister of C.*

Scenario 2:

Relations such as father of, mother of are intransitive, because the following inference with a negative conclusion is valid.

P is a father of Q

Q is a father of S

Query :*What is the relation between P and S?*

Expected Inference : *P is not a father of S.*

In each scenario, the relations such as sister of and father of between the concepts. But in scenario 2, it is very difficult to infer the relation because it has intransitive property and it is undefined. Reasoning algorithm should be designed to infer the relations between two different concepts, even the relations hold different properties. Suppose an argument contains multiple relations, reasoning algorithm may conclude invalid inferences.

Scenario 3:

Consider the following statements in family relationships as depicted in Figure 4.

X is a daughter of Y

Y is a sister of Z

Y is a sister of P

P is a mother of R

P is a daughter of Q

Z is a father of W

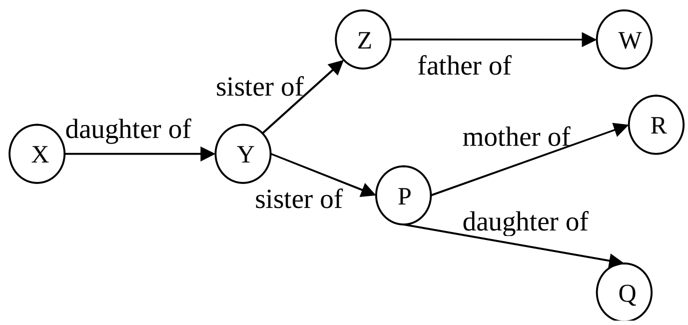

Figure 4. Family Relationships

In this example, *sister of* relation hold transitive and reflexive properties. Other relations such as *daughter of, mother of* and *father of* hold intransitive properties. The end user given the query

Query:"*What is the relation between X and R*?"
Expected Inference :*X is a sister of R*

An intelligent system can infer the relation between the concepts. To achieve such kind of effective reasoning, the knowledge should be represented properly including the logical properties of the relations and an efficient reasoning algorithm should be designed. Consider another scenario, the novice wishes to search about the following query in tourism ontology which is shown in Figure 5.

Query : "List the *desert tourist places which provide 5 star hotel accommodation facility*"

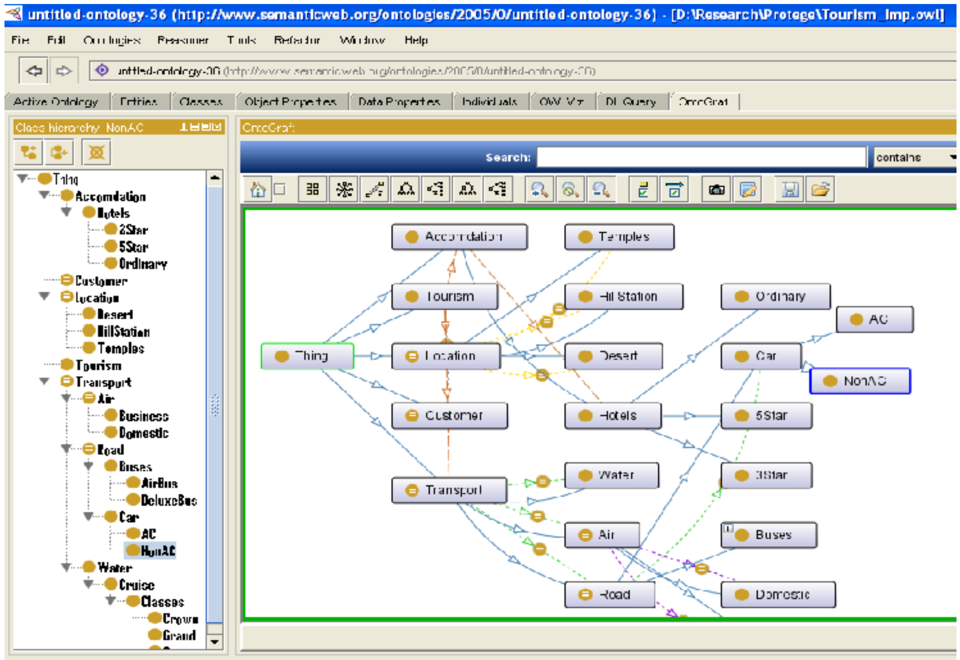

Figure 5. Tourism Ontology

Generally, they will give the keyword as "*tourist place and desert and 5 star*". When the system infers the semantics between the terms, it could retrieve the relevant documents. The above scenarios, clearly explained the key role of semantic relations in reasoning and searching. From the discussion it is clear that the research focus more on semantic relations is still an open area to achieve effective reasoning, searching and ranking.

6. CONCLUSION

In this paper, various semantic relations such as hypernym, hyponym, meronym, synonymy, antonymy, polysemy, case, cause-effect, paradigmatic, spatial and temporal have been discussed. This paper dealt about the properties of semantic relations and explained how the properties play a vital role in reasoning. It addressed the way in which classified relations have been used in various applications like reasoning, searching, ranking and auditing. It clearly shows the implication of relations in a wide range of domain. Semantic relations are used to achieve more appropriate reasoning and effective information retrieval. It has been evidently explained with several illustrations. In future, the researchers shall concentrate more on semantic relations to any of the domain to make the system most effective and exploitable one.

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