AN ONTOLOGY BASED APPROACH FOR SEARCHING NEIGHBORHOOD BUILDING

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ABSTRACT

We need store knowledge semantically and manage knowledge easily to make semantic web vision, a vision where the meaning of information played a far more important role than it does in today's Web, come trough. Using relational model, it is difficult to improve the model when knowledge growing up. This kind of modeling also has weakness such does not support dynamically in storing information in which much more semantically of the knowledge. Using ontology modeling to store the knowledge can solve this problem. Recently, there are still a few ontologies about location to store knowledge for spatial application.

In this paper we propose an OWL based location ontology to represent knowledge about the buildings in National Taiwan University (NTU) campus. We develop the ontology using protégé 3.2.1 and use Semantic Web Rule Language (SWRL) to infer new knowledge based on the knowledge. Based on knowledge about the first level connection of each building, we can infer new knowledge about the second level connection of each building. All of this knowledge will be used to find the route of building from location A to location B. We also propose a concept for searching the route from location A to location B in this ontology.

Using SWRL and Jess we can infer new knowledge and stored it in knowledge base as new facts. This project is a first step for our next step to develop the context aware system to find the route in indoor space and outdoor space for tour guide based on location ontology in National Taiwan University.

Keywords: *Location based ontology, infer new knowledge, SWRL.*

1. INTRODUCTION

The last decades, in many applications, data and information from domain knowledge is stored using the relational data model approach. This kind of modeling in this structure has weakness such does not support dynamically in storing information in which much more semantically of the knowledge. This approach also does not support well on searching process from different user's perceptions and even difficult to improve the model when knowledge growing up.

One of the main restrictions in relational data model approach is using concept to preserve consistency, remove redundancy and anomaly that done by develop the model in tables that relate each other in normal form. In the future, researchers effort continuously to develop process how to store data and information without change the information and keep the data semantically. One of the efforts now is using ontology approach.

Ontology can support knowledge management and open the possibility to change perception of storing process from document oriented to knowledge that relate each other, can be combined and reuse flexible and dynamic. Ontology describes formally a domain of discourse, typically consist of finite terms and the relationships between these terms, the terms denote important concepts. A few number of ontologies about location and application in location based give us motivation to do this research. Ontology can be used to answer the question / query semantically. As the example, using ontology we can find information about the nearest restoran from CSIE building.

In this paper, we present how to store NTU location knowledge using ontology approach and infer new knowledge from them using SWRL and Jess. This knowledge is useful to find the neighbor of each building. We also present step by step how to develop ontology using protégé in NTU location domain, how to write SWRL and use Jess in Protégé.

The rest of this paper is divided into 6 sections. In section 2, we introduce ontology definition, tool to build our ontology and our methodology to develop ontology and infer new knowledge. In section 3 we describe the design of our ontology to represent knowledge about location of buildings in NTU campus. Section 4 describe about our concept to search the path from source to target building. Section 5 provides the result in our experiments. Conclusion and future work is discussed in section 6.

2. METHODOLOGY

We have developed the ontology for NTU location building, store each building neighbors and extract second level of each building, the next neighbor of the neighbor, with general steps in figure 1.

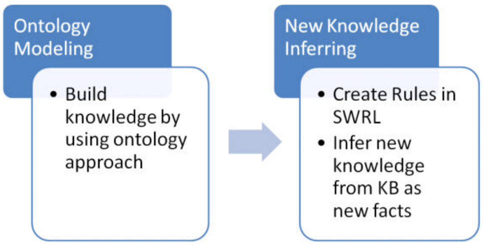


Figure 1. General steps

Section 2.1 and 2.2 describe the basic theory and the specific step we are used.

2.1 Ontology Modeling

The term ontology actually comes from philosophy. The meaning of ontology according philosophy is kind of things that actually exist and how to describe them. In computer science, ontology is defined as explicit and formal specification of a conceptualization that consists of finite list of terms and the relationships between these terms.

In the context of open environments (as in Semantic Web), ontology represent knowledge that formally specifies agreed logical theories for an application domain. The Semantic Web is propagated by the World Wide Web Consortium (W3C), an international standardization body for theWeb. The driving force of the Semantic Web initiative is Tim Berners-Lee, the very person who invented the WWW in the late 1980s. He expects from this initiative the realization of his original vision of the Web, a vision where the meaning of information played a far more important role than it does in today's Web and as an alternative approach to represent web content in a form that is more easily machine-processable. We can use ontology editor such protégé, Ontolingua, Chimaera, KAON, and et cetera to describe ontology or to do ontology modeling. Ontology can be expressed using OWL (Ontology Web Language). The OWL is designed for used by applications that need to process the content of information instead of just presenting information to humans. OWL facilitates greater machine interpretability of Web content that supported by Extensible Markup Language (XML), Resource Description Framework (RDF), and RDF Schema (RDF-S) by providing additional vocabulary along with a formal semantics. We use Protégé 3.2.1 to develop NTU location ontology.

There are some reasons why people develop ontology [5]; to share common understanding of the structure of information among people or software agents, to enable reuse of domain knowledge, to make domain assumptions explicit, to separate domain knowledge from the operational knowledge, and to analyze domain knowledge. Also, there are some approaches to develop ontology. Figure 2 shows step by step how to develop ontology.

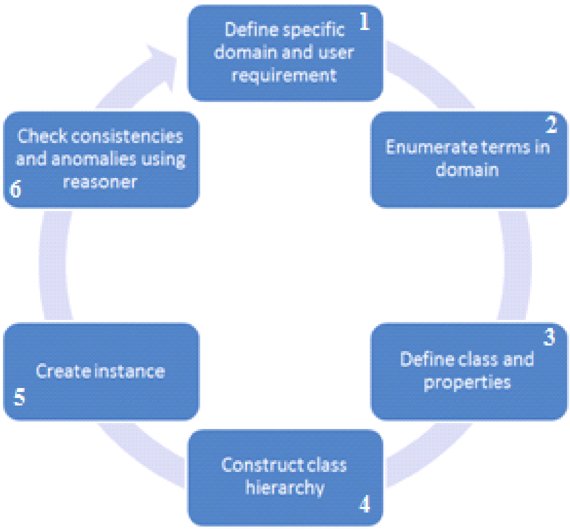


Figure 2. Step by step ontology modeling.

Based on approach that proposed by N.F. Noy [5], we developed ontology using these steps, as can be seen in figure 2:

1. Define specific domain and user requirement. Ontology is a model of a particular domain. We must define the particular domain we will be used and define user requirement. Some question can be addressed to find it, such as: what is the domain that the ontology will cover? For what we are going to use the ontology? For what types of questions should the ontology provide answers? Who will use and maintain the ontology?
2. Enumerate terms in domain. Before enumerate terms in domain, we can find information whether the ontology for our domain has define or not. If it has been defined by another people, we can reuse it. But if there is no ontology for our domain we must create it by ourselves. Enumerate terms can be done by write down in an unstructured list all the relevant terms that are expected to appear in the ontology. To simplify we can use Noun as the basis for class names (for example: region) and Verbs as basis for property names (for example: connect with)
3. Define class and properties. Define class and properties based on the list terms we are found in step 2. Class is a set that contain a set of individuals. Each class has properties. Property is relationship between two individual or characteristic of the class. Properties represent relationships between two individual. The other word of properties is slots. It links individual from domain and individual from the range. There are 3 types of properties :
   a. Object Properties
   b. Data Type Properties
   c. Annotation Properties

   Object property is property that link individual to an individual. Types of object property are inverse property (e.g. : has_parent inverse of has_child), functional property (e.g. : has_birthMother), transitive

property (e.g. : has_anchestor) and symmetric property (e.g. : has_sibling).
4. Construct class hierarchy. After the identification of relevant terms as class and properties, these terms must be organized in a taxonomic hierarchy. Opinions differ on whether it is more efficient / reliable to do this in a top-down or bottom-up fashion.
5. Create Instances. We develop ontology is not the goal, but we will use it to another application. We will fill the ontology with the fact or knowledge as instances.
6. Check consistencies and anomalies using reasoner. To avoid inconsistency in the ontology we need use reasoner to check the consistency.

2.2 Protégé

As we mention before, there are so many editor that are used to build ontology. In this research, we use Protégé 3.2.1 to build ontology. Protégé also has many plug-in that support the process to manage and maintain the ontology. For this research we use SWRL (Semantic Web Rule Language) to create and execute the rule for semantic web and Onto Viz plug-in to visualize an ontology.

2.2.1. SWRL plug-in

SWRL is intended to be the rule language of Semantic Web, it is based on OWL. All rules in SWRL are expressed in terms of OWL concepts (classes, properties, individuals, literals, etc). In protégé, SWRL is provided in SWRL Tab.

SWRL Tab is an extension to the Protégé-OWL plugin that permits the creation and execution of SWRL rules. In SWRL Tab, there is rules editor. The editor can be used to create SWRL rules, edit existing SWRL rules, and read and write SWRL rules. It also allows a variety of third-party rule engines to be plugged in to do inference. SWRL in protégé currently supports inference with the Jess rule engine.

2.2.2. Onto Viz Plug-in

By exploite an open source library optimized for graph visualization (Graphviz), the Onto Viz plug-in displays a protégé ontology as a graph. In this representation, nodes represent classes and instances and oriented arcs for visualizing the relations. Using this visualization, ontology can easy to be read and understood. Figure 6 represent ontology visualization using Onto Viz Plug-in.

2.3 Infer New Knowledge Using SWRL

Semantic Web Rule Language (SWRL) is intended to be the rule language of Semantic Web. Semantic Web is an evolving of the WWW in which web content can be expressed not only in natural language, but also in a form that can be read and used by software agents, thus permitting them to find, share and integrate information more easily. All rules in SWRL are expressed in terms of OWL concepts consist of classes, properties, individuals and literals.

The SWRL Plugin can support rule-based reasoning. SWRL editor in Protégé provide user ways to edit rules, supports inference with SWRL rules using the Jess rule engine and transfer knowledge (in OWL) as result of inference to be new knowledge. Figure 3 described our method to infer new knowledge using protégé, SWRL and Jess. After build ontology and add the knowledge as instances, It can be said that ontology is to be knowledge base. To infer new knowledge we use SWRL tab in protégé. Using this tab we can create new rule or edit it. We run the rules on knowledge based using Jess inference engine in SWRL tab and it will produce new knowledge. New knowledge is asserted to knowledge base as new facts using the last step, assert new knowledge to Knowledge Base (KB).

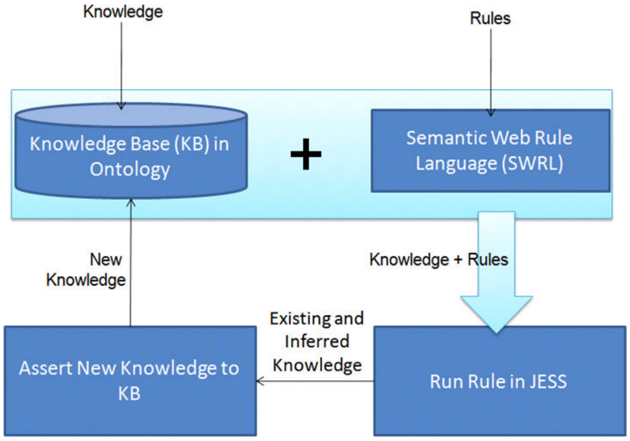


Figure 3. Infer new knowledge process

3. NTU LOCATION ONTOLOGY

The location information described by ontology is very efficient, especially in campus. The locations in campus not only have the geometric relations between them, but also can be categorized by the organization and the functions of the buildings. In this project, we focus on our school, National Taiwan University, to build the specified ontology of buildings and follow the official organization to setup the classes. The buildings in NTU have five different types: Academic Buildings, Administrative Units, Instructional Buildings, Life and Recreation Units, Dormitories and there are several colleges under academic buildings. This category knowledge is useful for search the same type buildings or some related units. Except the official classification, we still need the geometric knowledge in our campus ontology for basic building relations. To build NTU location ontology we use NTU campus map in figure 4 as basic knowledge. For experiment purpose, we only considered area in the square in NTU Campus map as described at figure 5.

In this project, we only implement one relation of the buildings, called “connectWith”, and one rule for inferring another important relation, called “connectLevel2”. As we can seen in figure 5, “arrow” describe the relation “connectWith”. We can say, building number 82 connectWith building number 45, 63, 84, 52 and 50. Because building number 50 connectWith building number 41, we can say that building number 82 connectLevel2 with building number 41. We use this relation because when looking for a building in the map, we always want to know which building is next to the others. For example, when we want to find where is department of sociology (45) and we have already know where is CSIE (82), we can say that the college of society is next to CSIE. That is why the "next to" information is important, so we set a property, connectWith, in the campus ontology for describing "next to" relation. The connectWith property is also called level 1 connection of buildings. This property lets users know buildings that are near by each building and is enough for this project to infer another new knowledge. Otherwise, we eliminate the direction information between neighboring buildings, because doing easily search or understanding the neighborhood of the buildings does not need to know the direction information.

Figure 4. National Taiwan University Campus Map

Figure 5. Area in NTU Campus Map for experiment

The figure 5 shows part of buildings in NTU and near by CSIE and their level 1 connection and the connectWith net is like the real map deploy of the buildings, except the direction issue. Based on this knowledge we build NTU location ontology building using protégé and step by step in figure 2. Figure 6 shows the class hierarchy of NTU location ontology and figure 7 shows part of OWL for NTU location ontology. Figure 7 describe about how to define CollegeofLifeScience as a class and sub class of AcademicBuildings class. Class Region is a subclass of Thing and has id_number as data type property and object property connectWith with type symmetric property.

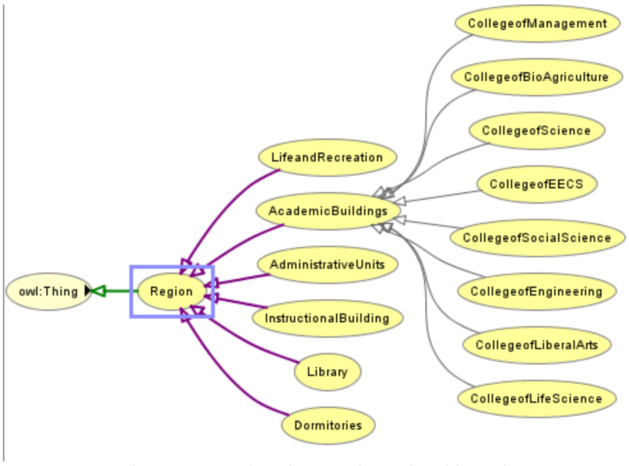


Figure 6. NTU location ontology class hierarchy

```
<owl:Ontology rdf:about="">
  <owl:imports rdf:resource="http://www.w3.org/2003/11/swrl"/>
  <owl:imports rdf:resource="http://www.w3.org/2003/11/swrlb"/>
</owl:Ontology>
<owl:Class rdf:ID="CollegeofLifeScience">
  <rdfs:subClassOf>
    <owl:Class rdf:ID="AcademicBuildings"/>
  </rdfs:subClassOf>
</owl:Class>
<owl:Class rdf:about="#Region">
  <rdfs:subClassOf rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty>
        <owl:DatatypeProperty rdf:ID="id_number"/>
      </owl:onProperty>
      <owl:maxCardinality rdf:datatype="http://www.w3.org/2001/XMLSchema#int"
      >1</owl:maxCardinality>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
<owl:SymmetricProperty rdf:ID="connectWith">
  <owl:inverseOf rdf:resource="#connectWith"/>
  <rdfs:domain rdf:resource="#Region"/>
  <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#ObjectProperty"/>
  <rdfs:range rdf:resource="#Region"/>
</owl:SymmetricProperty>
```
Figure 7. OWL for NTU location Ontology

By using the basic first level connection information, we can infer another new knowledge "level 2 connection" and we write the rule in figure 8 via SWRL and JESS. The second level connection is defined by a building that near by another building's neighboring building, so we can use the first level connection information to infer the second level connection. In figure 9 shows the first level connection for all buildings as original knowledge. These connections give more information about a building and its neighbors. From this figure we can find the neighbors of CSIE Building are Graduate Institute of Applied Mechanics, college of Engineering Building, Electrical Engineering Building 2, Barry Lam Hall and Department of Sociology. When we want to do the guidance or the path search, the level information of the buildings, like building hopping, is essential.

```
Region(?x) ∧
Region(?y) ∧
Region(?z) ∧
connectWith(?x, ?y) ∧
connectWith(?y, ?z) ∧
differentFrom(?x, ?z) ∧
notConnectWith(?x, ?z)
 → level2Conn(?x, ?z)
```

Figure 8. Rule to infer second level connection

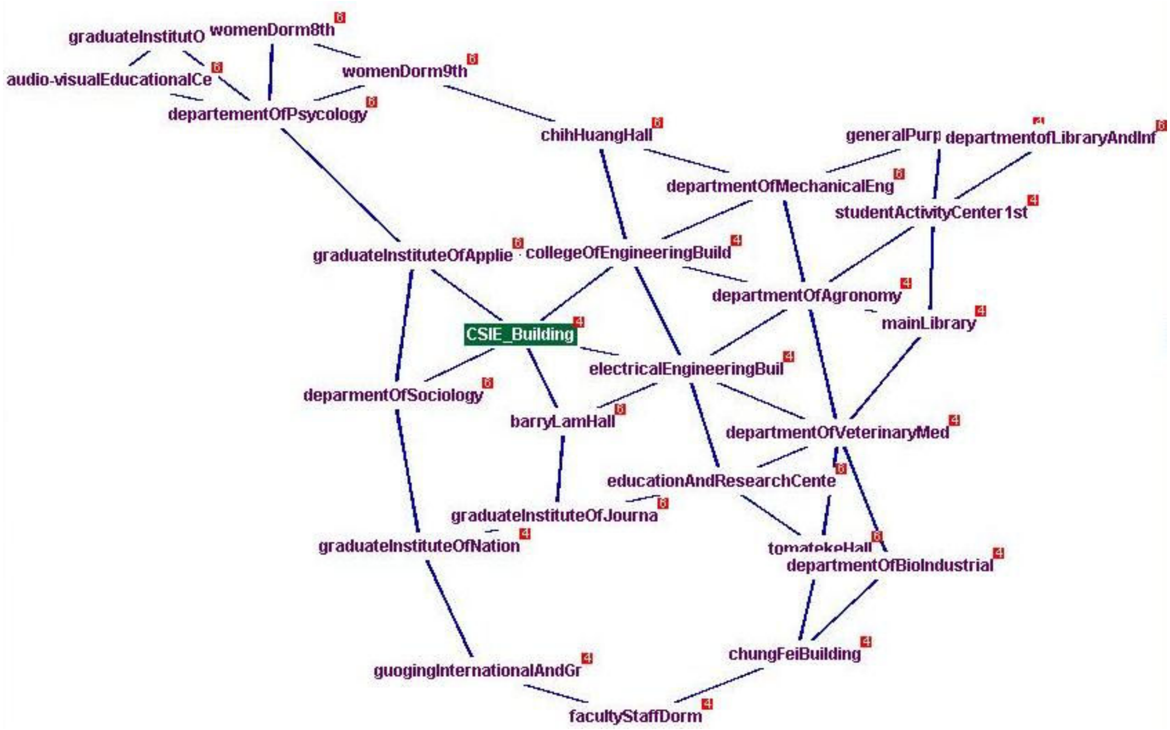


Figure 9. Level 1 connection for all buildings

4. SEARCHING CONCEPT

In the previous section, we have the information of target building and its first level and second level connection buildings which are pre-defined and inferred knowledge. We also can infer more levels by writing more SWRL rules. The figure 10 shows the illustration of the target building and the connections, limited in two levels. The levels give us enough information to find a path between one building and another.

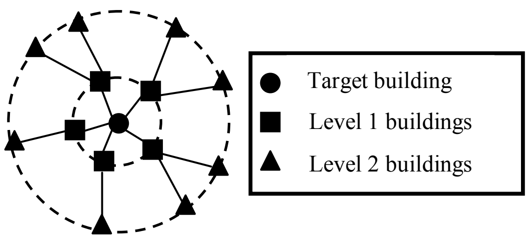
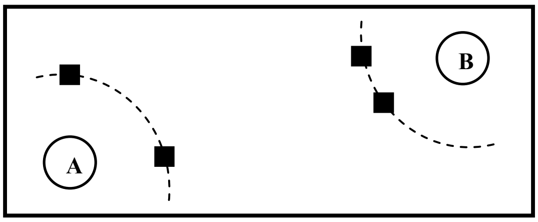


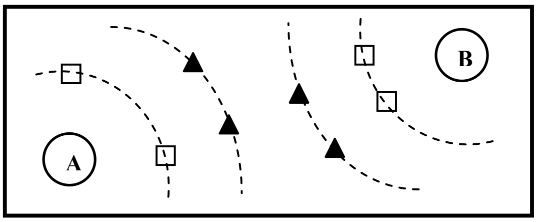
Figure 10. Illustration of target building and its connections

The path finding method in our project is like the sonar to look for one level connections and one building can do the sonar search at the same time. The searching detects another side building of the path and the same connection building of each target building. In figure 11 (a), using the source building A, our method try to find another target building B by detecting first level of building A and recognize all of its first level connections that one of them is the same as building B's connection. And then, using Building B we do the same searching. When the searching is failed, the target building keeps detecting next level, like figure 11 (b). The figure 11 (c) displays the result of searching from building A detects the third level and we find there is a connection with building X is the same as the connection of building B in second level. Finally, in figure 11 (d), we can link the path level by level and finish the path finding. If there are many paths, using this method we can find the shortest path. This searching method is like bidirectional search and the limited level is like the iterative deepening algorithm. Combining these two searches should be more efficient in the map which is built on the location ontology.

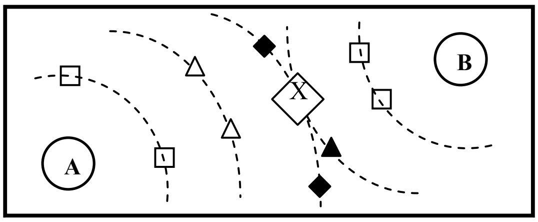
Breadth-first search (BFS) optimal for the shortest path and complete, it means the solution is reached if it exists. The time complexity and memory (space) complexity for BFS is the same, exponential in the depth of the solution and every node is kept in the memory. In other hand, depth-first search (DFS) is not optimal and complete but space complexity is linear in the maximum depth of the search tree, eventhough the time complexity is exponential, the same with BFS. Iterative deepening algorithm (IDA) combines advantages of the BFS and DFS with only moderate computational overhead. This search is complete and optimal for the shortest path. Time complexity for IDA is exponential and space complexity is linier. Using bidirectional method we search from both initial (start) state and goal (target) state and the time and space complexity is a half of BFS.



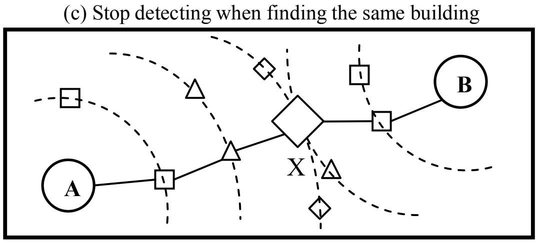
(a) Detect first level connections



(b) Detect second level connections



(c) Stop detecting when finding the same building



(d) Connect the found buildings to be the searching path

Figure 11. Searching Process

5. EXPERIMENT AND RESULT

In this experiment we use 28 instances building in ontology and their property. We only fill “connectWith” property. After we run rule in Jess inference Engine, we get 77 new knowledge for second level connection as the inference result. Figure 12 shows first and second level connection in ontology. We can see first level connection of CSIE building is the same with original knowledge base and after do inference we can find the second level connection as shown in figure 12.

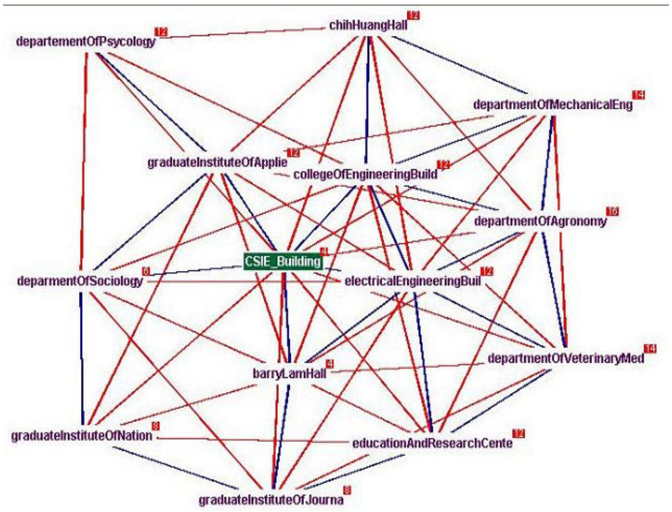


Figure 12. First and second Level connection for CSIE building

6. CONCLUSION AND FUTURE WORK

There has been spatial ontology built for pervasive computing such as SOUPA [2]. Our project adopted SOUPA ontology to represent location ontology and we will use some of concept in SOUPA in our next project. In this project we only consider about the location about each building refer to another building. We do not consider about the road to go from one building to another building. Although we only have limited information about location building, using SWRL we can infer new knowledge from it.

This project is the first step for our goal to develop context aware system to find the route in outdoor space and indoor space. Using this basic knowledge we will develop application to find the route for tour guide based on ontology in National Taiwan University, for the next project we will consider about road knowledge and another public service location. In our next project we will use spatial ontology and time ontology in SOUPA to deal with context aware in location domain. We also will use standard for location based services, the OpenGIS Location Service (OpenLS) specification [1], to deal with service for tour guide using pervasive computing service. This research also can be used as basic step for future work about application for network antenna or network pipe line in water and gas company.

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