1. Introduction

1.1. The purpose of this study

Existing knowledge organization systems, such as academic glossaries or thesauruses, struggle to capture the variety of semantic relationships between terminologies because they simply define the terms or define only the broader, narrower and related concepts. To overcome these problems, much research has been conducted on new knowledge structures, such as the various ontologies based on thesauruses or the thesauruses containing definitions of terms.

In this study, we propose a structural academic glossary as a new form of knowledge organization system to overcome the limitations of existing knowledge structures. The structural academic glossary described in this study defines each academic term depending on various conceptual categories (hereafter classes) with many properties. In the structural academic glossary, each term belonging to the same class is defined based on the properties of that class. This study starts with the assumption that it is possible to search semantically relevant terms efficiently if we generate inference rules based on setting up properties, classes, and relationships about terms through constructing a structural academic glossary database.

For the experiment, we constructed a structural academic glossary based on a relational database system targeting author keywords of journal articles in the fields of the humanities, social sciences, arts, and sports in the Korea Citation Index (hereafter KCI). The official name of this system is “Structural Terminology Net (hearafter STNet)”, and the web address is http://stnet.re.kr. Then, we evaluated semantic search results applying inference rules generated by converting the RDB data of STNet into RDF ontology.

1.2.Related Works

In Philosophy, ontology is the study of describing the kinds of things that exist in the world and how they are related. In information science, ontology is used to refer to a body of knowledge describing the sorts of objects, properties of objects, and relations between objects that are possible in a specified domain. Ontology can be applied in many domains and a survey of Meenachi & Baba (2012) presented on the usage of ontology in various domains like Medical, Agriculture, Geosciences, Education, Marine, Communication, Computer, Chemical, Defence, Linguistic *et cetera.*

Currently there are a significant number of researches to deal the issue of ontology building methodology. The research can be divided essentially in two approaches. The first collects terminology and builds the ontology by analyzing concepts, forming a taxonomy for the concepts, and defining the relationships between the concepts and the rules for acquiring domain knowledge. This work takes four directions; the bottom-up method, the top-down method, the middle-out method, and the hybrid method. The bottom-up method starts with specific concepts and then groups them into general concepts (Grüninger & Fox 1995, Van Der Vet & Mars 1998). The top-down method starts with the general classes and then divides these into sub-classes (Schreiber, Wielinga, & Jansweijer 1995). The middle-out method starts with certain mid-level concepts and then applies the bottom-up method or the top-down method (Corcho et al. 2005, Yoo, No, & Ra 2014). The hybrid method merges ontologies developed from the bottom-up method and top-down method into one ontology (López-Pellicer et al. 2008).

The second approach to ontology building involves developing an ontology from database schemas. Many methods have been reported for connecting with transferring relational database to ontology structure (Michel, Montagnat, & Faron-Zucker 2013). One of the aspects that existing methods can be classified based on it is the type of the source of transmission. They are roughly classified into one of the five categories; approaches based on an analysis of relational schema (Stojanovic, Stojanovic, & Volz 2002, Li, Du, & Wang 2005, Sane & Shirke 2009, Dong 2013, Thuy et al. 2014), approaches based on an analysis of tuples (Astrova 2004, Sonia & Khan 2008), approaches based on HTML pages (Astrova & Stantic 2005, Benslimane et al. 2006), approaches based on Entity Relationship (ER) or Extended Entity Relationship models (EER) (Xu et al. 2004, Upadhyaya & Kumar 2005, Trinkunas & Vasilecas 2007, Zhou, Xu, & Liu 2011, Russo et al. 2012), and approaches based on Structure Query Language (SQL) (Tirmizi, Sequeda, & Miranker 2008, Astrova 2009, Dadjoo & Kheirkhah 2015).

One of the problems in the areas of information storage and retrieval is the lacking of semantic data. According to support of semantic management in relational databases, there is a need to convert the database to the knowledge base. The most challenges related with methods proposed in the field of ontology generation from relational database is the correctness and accuracy of generated knowledge (ontology).

1.3.Process and Methodology

The structural terminology based ontology proposed in this paper is generated from the relational database schema of STNet. For accomplishing this work without error, the rules of generating RDF from relational databases at metadata level are used and they are classified as concepts, properties (predicates), instances and restrictions. The rules for concepts, properties and instances give a description of the correspondence at metadata level, which avoid migration of the large amount of data.

This study involved (a) constructing an STNet database, (b) generating and verifying ontology structure, (c) converting STNet data into RDF ontology, and (d) creating and evaluating inference control rules. (Refer to Figure 1) These processes are described below.

First, we chose approximately 55,000 author keywords from journal articles published between 2007 and 2012 in the fields of the humanities, social sciences, arts, and sports in KCI and then built the STNet database. Database construction was carried out over a period of three years from September 2012 to August 2015, and work on the database is ongoing. The standards for the selection of keywords for STNet database are commonly used in journal articles (Ko et al. 2013).

Second, we generated the structure of classes for all classes in the STNet database and analyzed the relationship types of real input data linked with classes and properties to set up 'ObjectType Property' and 'DataType Property'. After that, we defined ‘Domain’ and ‘Range’ for all STNet data and then verified any logical errors of each class and property via an inference engine. The inference engine we used is ‘Pellet’, a Description Logic inference engine supporting DIG interface based on Tableaux algorithms.

Third, after verifying any logical errors in ontology structure, we converted the STNet RDB data into RDF data. We used a ‘D2RQ’ RDF ontology converter that has been found suitable for dynamic RDBs, in which relationships between data changes or new data are added frequently (Ko, Lee, & Song 2015). We converted RDB data into RDF data, using an SQL script to retain class structures generated in the second process (Bumans, 2010).

Fourth, we defined inference control rules based on the types of classes and properties that contained above-average data after calculating the input ratio of the STNet data imported in the ontology conversion. Then, we evaluated the semantic search results using a SPARQL query about the very complicated search scenario related to the terminologies of the STNet database, one in which it is very difficult to deduce a result value by a simple keyword search.

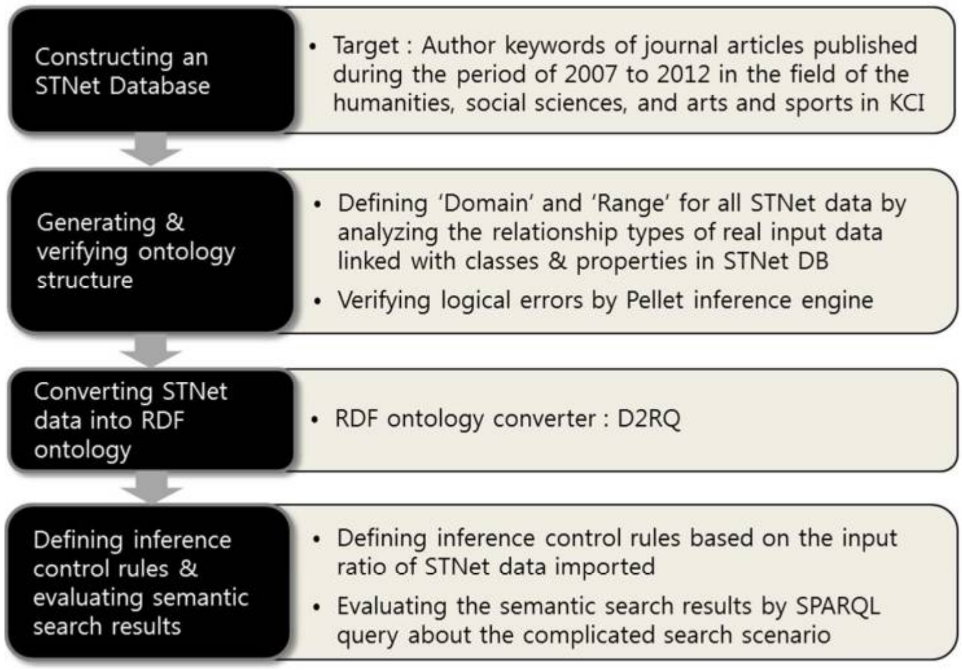


Figure 1 Research Process

2. Structural Terminology Net (STNet)

2.1. STNet Database

As of December 31, 2015, there are 55,236 defined academic terms in the STNet database, which was constructed for author keywords from journal articles in the fields of the humanities, social sciences, arts, and sports in KCI. There are 72,839 data (object type) in 'Object Type Property', 25,984 data (system code or text value) in 'Data Type Property', and 209,701 relationships between terms linked by relation predicates. (Refer to Table 1)

Table 1 Current state of the STNet database (as of December 31, 2015)

Division	Current situation	
Number of terms		**55,236**
Number of data in Properties	Object type	72,839
	Code type	7,251
	Text type	18,733
	Subtotal	**98,823**
Number of links between terms by relation predicates	Equivalent relationships	21,982
	Hierarchical relationships	66,995
	Associative relationships	120,724
	Subtotal	**209,701**

2.2. STNet Taxonomy

STNet taxonomy consists of 7 top level classes, 27 middle level classes and 143 lower level classes as of December 31, 2015. (Refer to Appendix A) Lower level classes are subdivided into the 1st lower level and the 2nd lower level. Each class has a code and a class name and is structured by (conceptual) properties that represent the class. Each property has a value that can be divided into 'object type', 'code type', or 'text type'. Among them, the object type value represents the input terminology in the STNet database. (Refer to Figure 2)

2.3. STNet relation predicates

STNet terms connect to the other terms that are used by property values of that class or that belong to other classes . (Refer to Figure 2) In other words, the term that belongs to the 'Title_of_Literature' class has a relationship with the values in properties of that class, such as 'hasCreator' or 'hasPublicationYear'. For example, the 'The Diary of a Young Girl: Anne Frank' term of the 'Title_of_Literature' class has connections with 'Anne Frank' of the 'has Creator' property and '1947' of the 'hasPublicationYear' property. Additionally, 'The Diary of a Young Girl: Anne Frank' term can have an interrelationship with the 'World War Ⅱ' term in another 'Event_Name' class through a relation predicate, such as 'isAffectedBy↔affects'.

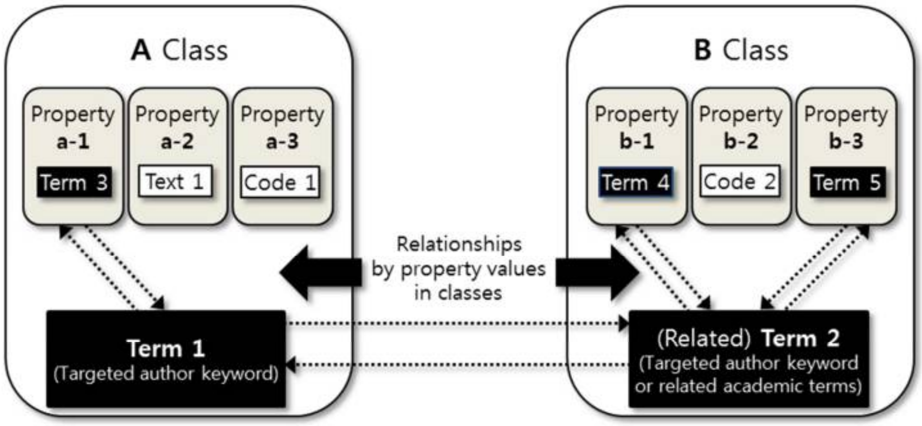


Figure 2 Connections of classes and properties in the STNet

All academic terminology in STNet can have classes from the taxonomy and can thus be defined by the properties of those classes. Furthermore, semantic relationships, such as 'class to class', 'class to property', 'property to another property', and 'term to term', can be described by the relation predicate. (Refer to Appendix B)

2.4. STNet Data Model

The purpose of the STNet data model is to manage terminology in the system. It is configured to add the information about terms, relationships, and classes on the group of terms that are selected as build-up objects. (Refer to figure 3) By proceeding to build the database in the form of modeling using a workbench, input data may be found both at the conceptual semantic network and thesaurus-based semantic network in the future. Therefore, 'morphological and structural' features and 'conceptual and semantic' features of terminology can be analyzed in the STNet system at the same time.

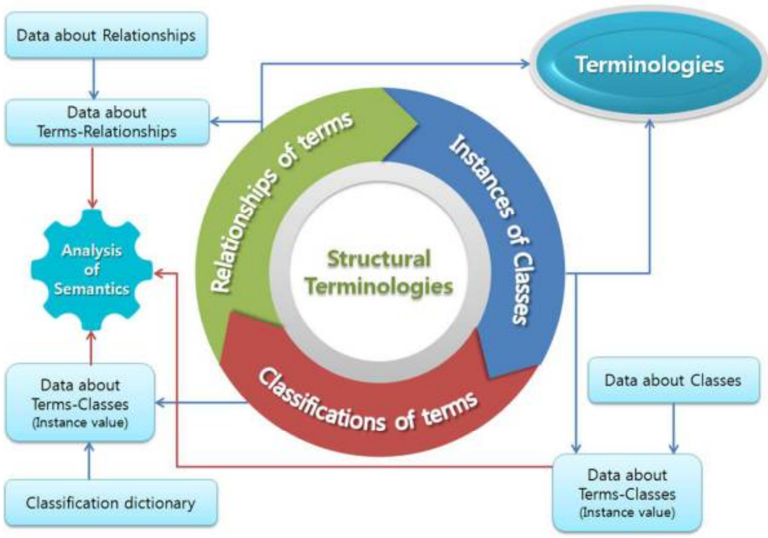


Figure 3 STNet data model (Terminology-centered)

2.5. STNet System

The STNet system was designed with a division between the 'Application layer' and 'Storage layer' built into database construction. Additionally, to manage the structure of the glossary, the managing part was divided into two functions for the schema and for the reference items. A STNet system structure diagram is shown in Figure 4.

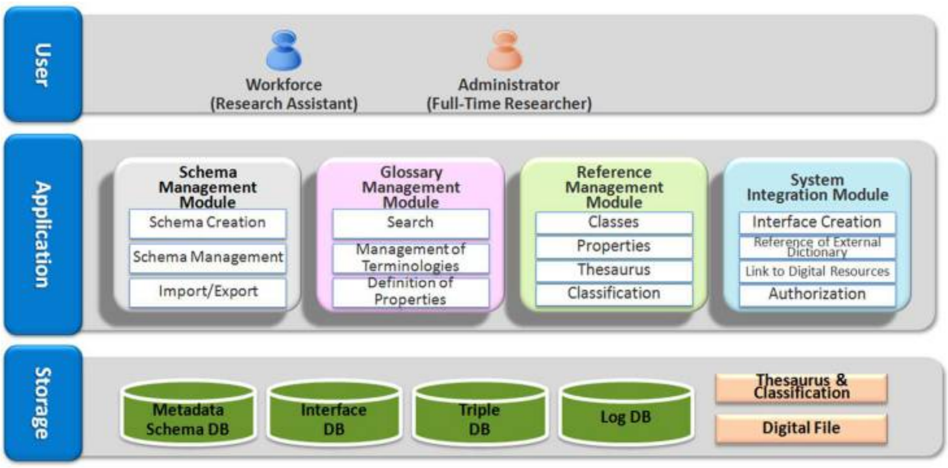


Figure 4 STNet system structure diagram

The STNet system has functions that can define a newly added term by searching the database for the selected terms. In the left part of Figure 5, a search for the selected terms is implemented. (Refer to Figure 5)

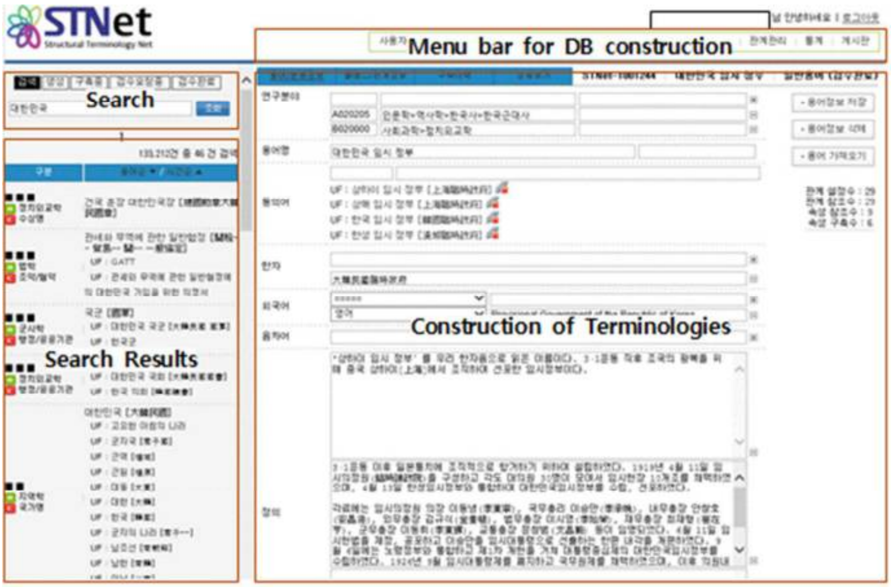


Figure 5 Screenshot of searching and inputting terms in the STNet

3. Generation and verification of ontology

We verified the errors of the sample data applied to the ontology structure by using an inference engine after converting the extracted partial samples among all STNet data into RDF ontology. After verifying and modifying the sample data, we converted and imported 55,177 terms linking with properties in the 170 classes of the STNet database into RDF ontology. The ontology was converted by connecting data with the generated structure after generating the classes and properties of classes used in the STNet (Lin, Xu & Ding 2013). The settings for the conversion were as follows: 'Knowledge Source' was 'RDB Schema and Data', 'Ontology Language' was 'RDFs', and 'Degree of Automation' was 'semi-automatic'.

3.1. Setting up ontology classes and OWL properties

We composed ontology classes in the form of OWL-DL based on the conceptual scopes in the STNet. Additionally, in light of the interrelationships among classes, we configured 'Disjoint' to the classes that shared the same properties or had no semantic correlations with the others. Then, we defined 88 'ObjectType Properties' and 40 'DataType Properties' by analyzing the types of relations among real input terminologies in STNet. In the case of 'ObjectType Property', we set up the 'InverseOf' and 'Reflexive' relations, and 'Domain' and 'Range' according to the structure of the properties of classes. We also accorded 'Range' such as String, DateTime, and Integer to ‘DataType Property’ by referring values (code or text) about properties in the STNet. (Refer to Figure 6)

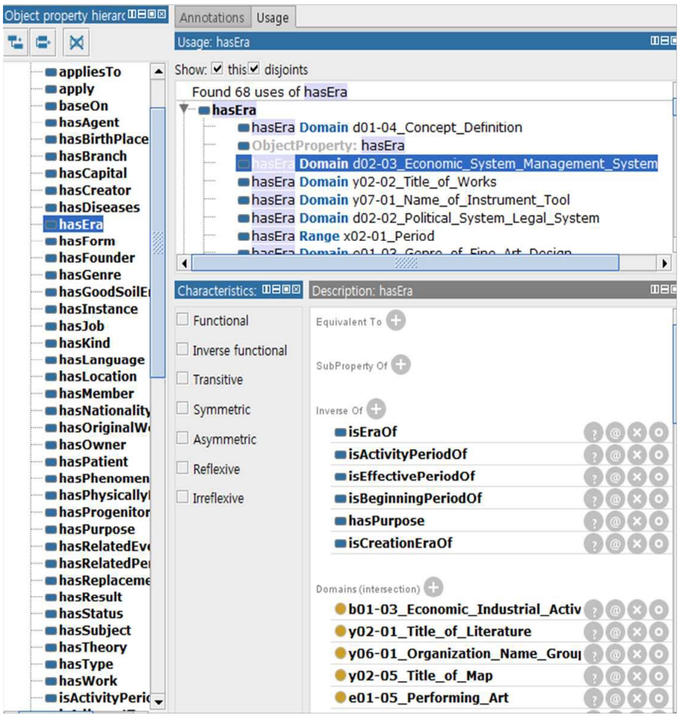


Figure 6 Example of setting up ‘ObjectType property’ (Target: hasEra)

3.2. Ontology verification

We verified errors in the ontology structure, which contains classes and properties in accordance with ALI(D) using the Pellet inference engine because STNet ontology was composed in OWL-DL. ALI(D) is a type of expression rule about DL (Description Logic). The results for ‘Displayed Class Inferences’, ‘Displayed Object Property Inferences’, ‘Displayed Data Property Inferences’, and ‘Displayed Individual Inferences’ showed no errors in the STNet ontology structure, as shown in Figure 7.

Figure 7 Verification result by Pellet inference engine

3.3. Construction of axiom sets

As mentioned above, we applied ontology schema completed with verification of ontology structure to the STNet instance data. Then, we constructed axiom sets about all classes in the STNet, after verifying errors about data using the Pellet inference engine again. Figure 8 shows examples of connections with 'Subject part (Domain)' or 'Predicate part (Range)' when the 'y01-01 Real_Person' class has connections with other related classes having property values such as 'Advocate↔advocatedBy', 'hasBirthPlace↔isBirthPlaceOf', and 'hasEra↔isActivityPeriodOf'.

Figure 8 Axiom example of 'y01-01 Real_person' class with constraint conditions

3.4. Converting STNet data into RDF ontology

We converted the STNet RDB Data into RDF ontology using the D2R server (http://d2rq.org). At the start of this process, we defined target data and set up property values about that data. Then, we used converted scripts in D2RQ form to convert RDB data into RDF data (Refer to figure 9). Additionally, after creating the D2RQ mapping languages, we checked and modified the errors regarding target data through 'd2r-query', provided by the D2R Server.

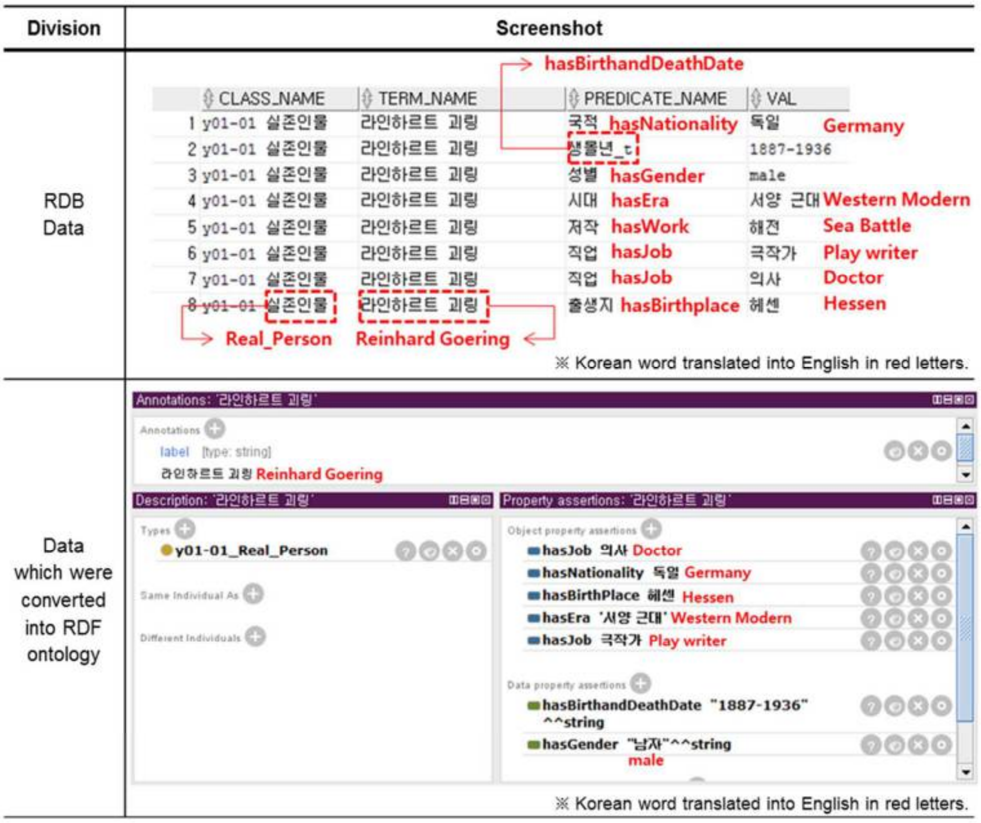


Figure 9 Result of converting RDB data into RDF ontology

The final converted RDF ontology file is found at the webpage <http://www.stent.re.kr/ontology.owl>, as shown in Figure 10.

```
<?xml version="1.0"?>

<!DOCTYPE Ontology [
    <!ENTITY xsd "http://www.w3.org/2001/XMLSchema#" >
    <!ENTITY xml "http://www.w3.org/XML/1998/namespace" >
    <!ENTITY rdfs "http://www.w3.org/2000/01/rdf-schema#" >
    <!ENTITY rdf "http://www.w3.org/1999/02/22-rdf-syntax-ns#" >
]>

<Ontology xmlns="http://www.w3.org/2002/07/owl#"
     xml:base="http://www.stnet.re.kr/ontology"
     xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
     xmlns:xml="http://www.w3.org/XML/1998/namespace"
     xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
     xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
     ontologyIRI="http://www.stnet.re.kr/ontology">
    <Prefix name="" IRI="http://www.w3.org/2002/07/owl#"/>
    <Prefix name="owl" IRI="http://www.w3.org/2002/07/owl#"/>
    <Prefix name="rdf" IRI="http://www.w3.org/1999/02/22-rdf-syntax-ns#"/>
    <Prefix name="xsd" IRI="http://www.w3.org/2001/XMLSchema#"/>
    <Prefix name="rdfs" IRI="http://www.w3.org/2000/01/rdf-schema#"/>
    <Declaration>
        <Class IRI="#A01_Human"/>
    </Declaration>
    <Declaration>
        <Class IRI="#A02_Institution_Organization"/>
    </Declaration>
```

Figure 10 Screenshot of the converted STNet ontology (http://www.stnet.re.kr/ontology.owl)

4. Definition of inference control rules and evaluation of semantic search

4.1. Definition of inference control rules using imported data

To define the generalized inference control rules for the STNet, we set up inference control rules based on the types of classes and properties that contained above-average (24 or more) data after calculating the sorts and the numeral values of input data in the form of 'Subject(X Class)↔Predicate(Property)↔Object(Y Class)' regarding STNet data imported in the process of ontology conversion. (Refer to Table 2) The reason we implemented the work as above was to make efficient rules that could minimize logical errors in the process of terminology searching because one term can belong to the many classes, and the property values in X class can connect with many related Y classes. For example, input terms in the 'hasWork' property of the 'Real_Person' class can belong to 'Title_of_Works', 'Title_of_Literature', 'Monument_Name_Cultural_Asset_Name', 'Performing_Arts', 'Title_of_Documents', and so on.

Table 2 Definition example of inference control rules

Subject(X Class)	Predicate(Property)	Object(Y Class)
y01-01_Real_Person	hasEra	x02-01_Period
	isMemberOf	y06-01_Organization_Name_Group_Name
	advocate	d01-01_Theory_Thought
	hasWork	y02-02_Title_of_Works y02-01_Title_of_Literature

1-1 'Real_Person' X ↔ 'hasEra' ↔ 'Period' Y
(=X is(was) in act during Y)'
1-2 'Real_Person' X ↔ 'isMemberOf' ↔ 'Organization_Name_Group_Name' Y
(=X is(was) a member of Y)
1-3 'Real_Person' X ↔ 'advocate' ↔ 'Theory_Thought' Y
(=X advocates(-ed) Y)
1-4 'Real_Person' X ↔ 'hasWork' ↔ 'Title_of_Works / Title_of_Literature' Y
(=X creates(-ed) Y)

4.2. Inference logic verification by Tbox

As STNet was made by OWL-DL, we used 'Description Logic' that was suitable for OWL-DL based inference for verification. Then, we verified the inference logic using a TBox because the STNet database was still being constructed.

When a TBox meets a random concept, it verifies axioms such as subclass, sibling, and disjointness about class structures by checking the classification inference, the subsumption inference, and the consistency inference. Regarding the verification results by TBox using FaCT++ and Pellet (Refer to Figure 11), all were true to the ‘Description Logic’ containing the above inference control rules. (Refer to Table 2)

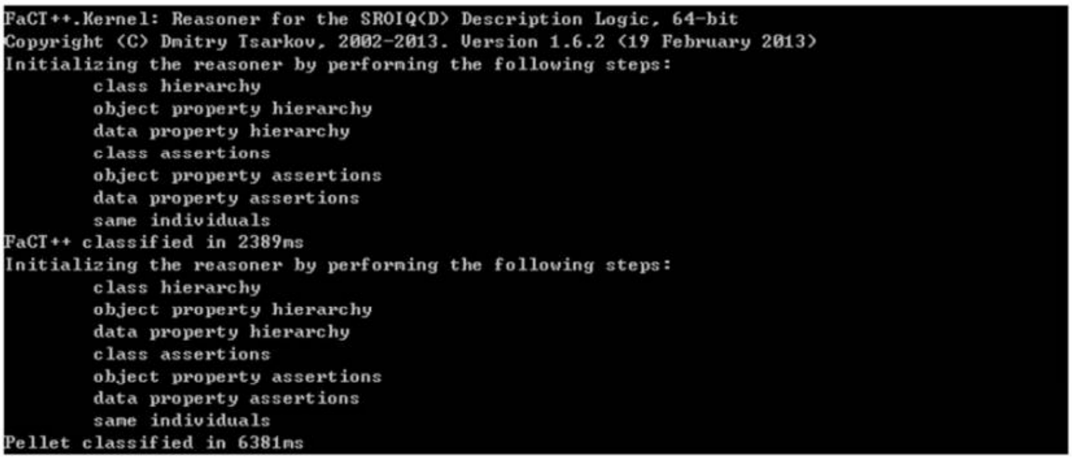
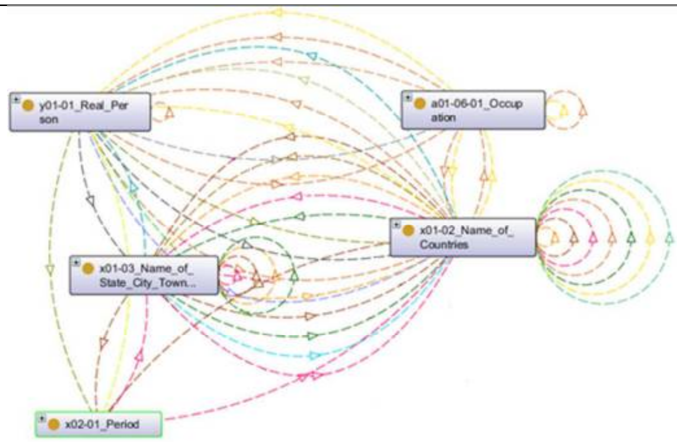


Figure 11 Verification results by Tbox using FaCT++ and Pellet inference engine

4.3. Evaluation of SPARQL query and search results

We extracted SPARQL query results for the very complicated search scenarios for which it was too difficult to deduce a result value via a simple keyword search. (Refer to Table 3-9)

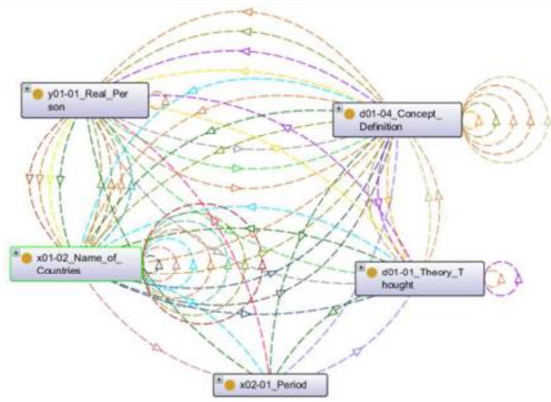
Table 3 Ontology Structure and Query Results of Scenario 1

<table>
<tr><td>Scenario 1</td><td>[Real_Person] was born in [Name_of_State_City_Town/Name_of_Countries] with the nationality of [Name_of_Countries] and was active in the period of [Period] as a [Occupation].</td></tr>
<tr><td>Ontology Structure</td><td>
</td></tr>
<tr><td>SPARQL Query</td><td>PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.stnet.re.kr/ontology#>

SELECT ?Location1 ?Nationality ?Era ?Job ?Person

WHERE {
?Location1 rdf:type :x01-03_Name_of_State_City_Town_Street_Avenue.
?Nationality rdf:type :x01-02_Name_of_Countries.
?Era rdf:type :x02-01_Period.
?Person rdf:type :y01-01_Real_Person.
?Job rdf:type :a01-06-01_Occupation.
?Person :hasBirthPlace ?Location1.
?Person :hasNationality ?Nationality.
?Person :hasEra ?Era.
?Person :hasJob ?Job.
}</td></tr>
<tr><td>Query Results</td><td>
<table>
<tr><th>[Name_of_State_City_Town/Name_of_Countries]</th><th>[Name_of_Countries]</th><th>[Period]</th><th>[Occupation]</th><th>[Real_Person]</th></tr>
<tr><td>경기도 (Gyeonggi-do)</td><td>대한민국 (Republic of Korea)</td><td>일제강점기 (Japanese Colonized Period)</td><td>교수 (Professor)</td><td>이선근 (Lee, Seongeun)</td></tr>
<tr><td>강원도 (Gangwon-do)</td><td>대한민국 (Republic of Korea)</td><td>일제강점기 (Japanese Colonized Period)</td><td>정치인 (Politician)</td><td>조일명 (Cho, Ilmyeong)</td></tr>
<tr><td>원산 (Wonsan-si)</td><td>북한 (North Korea)</td><td>일제강점기 (Japanese Colonized Period)</td><td>극작가 (Play Writer)</td><td>박영호 (Park, Yeongho)</td></tr>
<tr><td>성주군 (Seongju-gun)</td><td>대한민국 (Republic of Korea)</td><td>일제강점기 (Japanese Colonized Period)</td><td>정치인 (Politician)</td><td>김창숙 (Kim, Changsuk)</td></tr>
<tr><td>청양 (Cheongyang-gun)</td><td>북한 (North Korea)</td><td>일제강점기 (Japanese Colonized Period)</td><td>연극배우 (Play Actor)</td><td>황철 (Hwang, Chul)</td></tr>
</table>
※ Korean word translated into English in brackets.
※ The total number of search results for scenario 1 is 461 and we tabulate just 5 results.</td></tr>
</table>

Table 4 Ontology Structure and Query Results of Scenario 2

Scenario 2	[Theory_Thought] advocated by [Real_Person] is opposed to [Theory_Thought 2] advocated by [Real_Person 2], and [Theory_Thought] is also related to [Theory_Thought 3] and [Concept_Definition]. [Concept_Definition] advocated by [Real_Person3] is related to [Period] and [Name_of_Countries].
Ontology Structure	

SPARQL Query

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.stnet.re.kr/ontology#>

SELECT
DISTINCT ?Person1 ?Theory1 ?Theory2 ?Person2 ?Theory3 ?Concept ?Era ?Country ?Person3
WHERE {
          ?Person1 rdf:type :y01-01_Real_Person.
          ?Person2 rdf:type :y01-01_Real_Person.
          ?Person3 rdf:type :y01-01_Real_Person.
          ?Theory1 rdf:type :d01-01_Theory_Thought.
          ?Theory2 rdf:type :d01-01_Theory_Thought.
          ?Theory3 rdf:type :d01-01_Theory_Thought.
          ?Concept rdf:type :d01-04_Concept_Definition.
          ?Era rdf:type :x02-01_Period.
          ?Country rdf:type :x01-02_Name_of_Countries.
          ?Theory1 :advocatedBy ?Person1.
          ?Theory1 :isOppositionOf ?Theory2.
          ?Theory2 :advocatedBy ?Person2.
          ?Theory1 :isOppositionOf ?Theory3.
          ?Concept :advocatedBy ?Person3.
          ?Person3 :hasEra ?Era.
          ?Person3 :hasNationality ?Country.
          ?Concept :hasLocation ?Country.
          ?Concept :hasEra ?Era.
}
```

Query Results

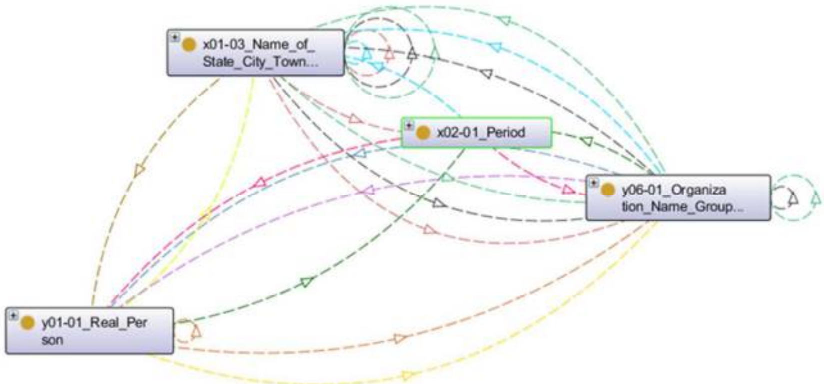
[Real_Person]	[Theory_Thought]	[Real_Person2]	[Theory_Thought2]	[Theory_Thought3]	[Concept_Definition]	[Real_Person3]	[Period]	[Name_of_Countries]
후설 (Husserl, Edmund)	형태심리학 (Gestalt – psychology)	플라톤 (Plato)	연합주의 (Associationism)	초월 철학 (Transcendental philosophy)	통각 (Apperception)	라이프니츠 (Leibniz, Gottfried Whilhelm von)	서양근대 (Western Modern)	독일 (Germany)
후설 (Husserl, Edmund)	형태심리학 (Gestalt – psychology)	플라톤 (Plato)	연합주의 (Associationism)	초월 철학 (Transcendental philosophy)	지향성 (Intention)	브렌타노 (Brentano, Franz)	서양근대 (Western Modern)	독일 (Germany)
주자 (Zhuxi)	본연지성 (Original Natural Tendency)	이정 (Er Cheng)	기질지성 (Physical Natural Tendency)	왕도 (Royal Rroad)	치양지 (Reach the Ultimate of Innate Wisdom)	왕양명 (Wang Shouren)	명시대 (Ming Dynasty)	중국 (China)
주자 (Zhuxi)	성리학적 세계관 (World View of Neo-Confucianism)	장자 (Zhuangzi)	도가사상 (Daoism)	왕도 (Royal Rroad)	치양지 (Reach the Ultimate of Innate Wisdom)	왕양명 (Wang Shouren)	명시대 (Ming Dynasty)	중국 (China)
주자 (Zhuxi)	성리학적 세계관 (World View of Neo-Confucianism)	노자 (Laozi)	도가사상 (Daoism)	왕도 (Royal Road)	치양지 (Reach the Ultimate of Innate Wisdom)	왕양명 (Wang Shouren)	명시대 (Ming Dynasty)	중국 (China)

※ Korean word translated into English in brackets.
※ The total number of search results for scenario 2 is 340 and we tabulate just 5 results.

Table 5 Ontology Structure and Query Results of Scenario 3

Scenario 3	[Real_Person] was affiliated with the [Organization_Name_Group_Name], which was founded by [Real_Person 2] from [Name_of_State_City_Town], and [Real_Person] was highly active in the period of [Period].

Ontology Structure



SPARQL Query

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.stnet.re.kr/ontology#>

SELECT ?RealPerson1 ?RealPerson2 ?OrganizationName_GroupName ?Era

WHERE {
        ?RealPerson1 rdf:type :y01-01_Real_Person.
        ?RealPerson2 rdf:type :y01-01_Real_Person.
        ?OrganizationName_GroupName rdf:type :y06-01_Organization_Name_Group_Name.
        ?Era rdf:type :x02-01_Period.
        ?RealPerson1 :isMemberOf ?OrganizationName_GroupName.
        ?OrganizationName_GroupName :hasFounder ?RealPerson2.
        ?OrganizationName_GroupName   :hasEra   ?Era
}
```

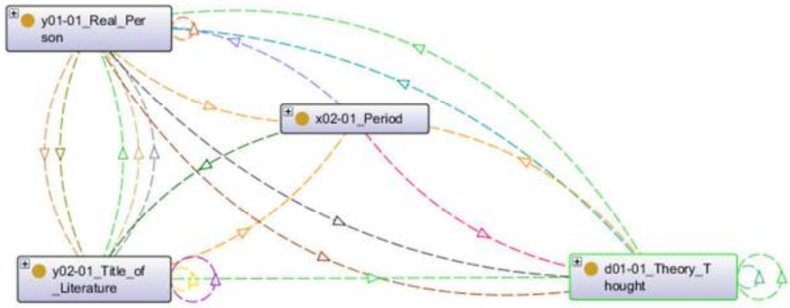
Query Results

[Real_Person]	[Organization_Name_Group_Name]	[Real_Person 2]	[Name_of_State_City_Town]	[Period]
최재형 (Choe, Jaehyung)	국민회 (National Society)	이승만 (Rhee, Syngman)	미국 (United States of America)	조선 후기 (Late Chosun Dynasty)
허익 (Heo, Ik)	국민회 (National Society)	이승만 (Rhee, Syngman)	미국 (United States of America)	조선 후기 (Late Chosun Dynasty)
알베르투스 마그누스 (Magnus, Albertus)	도미니크 수도회 (Dominican Order)	도미니쿠스 (Dominicus)	프랑스 (France)	서양 중세 (Western Middle Age)
도미니쿠스 (Dominicus)	도미니크 수도회 (Dominican Order)	도미니쿠스 (Dominicus)	프랑스 (France)	서양 중세 (Western Middle Age)
지롤라모 사보나롤라 (Savonarola, Girolamo)	도미니크 수도회 (Dominican Order)	도미니쿠스 (Dominicus)	프랑스 (France)	서양 중세 (Western Middle Age)

※ Korean word translated into English in brackets.

※ The total number of search results for scenario 3 is 142 and we tabulate just 5 results

Table 6 Ontology Structure and Query Results of Scenario 4

<table>
<tr><td>Scenario 4</td><td>[Title_of_Literature], which was written by [Real_Person] in the [Period], reflects the [Theory_Thought].</td></tr>
<tr><td>Ontology Structure</td><td>
</td></tr>
<tr><td>SPARQL Query</td><td>

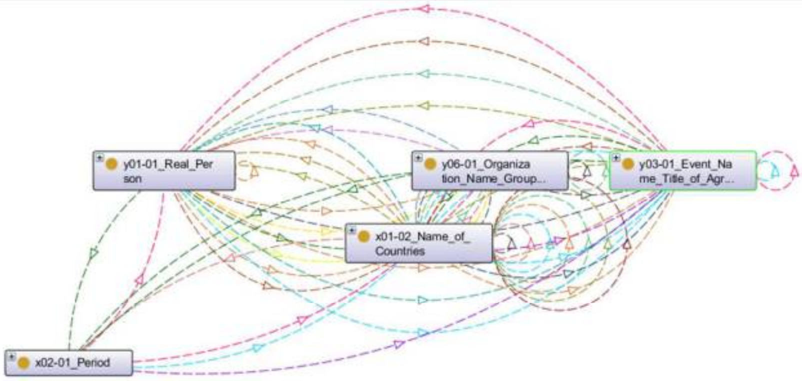
```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.stnet.re.kr/ontology#>
SELECT ?RealPerson ?Era ?Literature ?Works
WHERE {
        ?RealPerson rdf:type :y01-01_Real_Person.
        ?Literature rdf:type :y02-01_Title_of_Literature.
        ?Works rdf:type :y02-02_Title_of_Works.
        ?Era rdf:type :x02-01_Period.
        ?RealPerson :hasEra ?Era.
        ?RealPerson :hasWork ?Literature.
        ?RealPerson :hasWork ?Works
}
```

</td></tr>
<tr><td>Query Results</td><td>
<table>
<tr><th>[Title of Literature]</th><th>[Real_Person]</th><th>[Period]</th><th>[Theory_Thought]</th></tr>
<tr><td>주자대전차의집보
(Jujadaejeonchauijipbo)</td><td>이항로
(Lee, Hangro)</td><td>조선 후기
(Late Chosun Dynasty)</td><td>조선 성리학
(Noe-Confucianism of Chosun Era)</td></tr>
<tr><td>이륜행실도
(Iryunhaengsildo)</td><td>이병모
(Lee, Byungmo)</td><td>조선 후기
(Late Chosun Dynasty)</td><td>유교
(Confucianism)</td></tr>
<tr><td>경제야언
(A Rustic's Words on Governance(Kyŏngjeyaŏn))</td><td>우정규
(Woo, Jungkyu)</td><td>조선 후기
(Late Chosun Dynasty)</td><td>경세제민
(Governing a Nation and Providing Relief to People)</td></tr>
<tr><td>정신철학통편
(Jeongsincheolhaktongpyeon)</td><td>전병훈
(Jeon, Byunghoon)</td><td>조선 후기
(Late Chosun Dynasty)</td><td>계몽주의
(Enlightenment)</td></tr>
<tr><td>사의
(Rites of Classical Scholars(Sa Yui))</td><td>허전
(Heo, Jeon)</td><td>조선 후기
(Late Chosun Dynasty)</td><td>유가사상
(Confucian Thoughts)</td></tr>
</table>
※ Korean word translated into English in brackets.
※ The total number of search results for scenario 4 is 49 and we tabulate just 5 results.
</td></tr>
</table>

Table 7 Ontology Structure and Query Results of Scenario 5

Scenario 5	[Real_Person], who founded [Organization_Name_Group_Name], is a leader for [Event_Name_Title_of_Agreement] which occurred in [Name_Of_Countries] in the period of [Period], and the [Event_Name_Title_of_Agreement] is also related to [Real_Person 2].

Ontology Structure



SPARQL Query

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.stnet.re.kr/ontology#>

SELECT ?RealPerson1 ?OrganizationGroup ?EventName ?Era ?RealPerson2

WHERE {
        ?RealPerson1 rdf:type :y01-01_Real_Person.
        ?RealPerson2 rdf:type :y01-01_Real_Person.
        ?OrganizationGroup rdf:type :y06-01_Organization_Name_Group_Name.
        ?EventName rdf:type :y03-01_Event_Name_Title_of_Agreement.
        ?Era rdf:type :x02-01_Period.
        ?National rdf:type :x01-02_Name_of_Countries.
        ?OrganizationGroup :hasFounder ?RealPerson1.
        ?EventName :isManagedBy ?RealPerson1.
        ?EventName :hasEra ?Era.
        ?EventName :hasLocation ?National.
        ?EventName :hasRelatedPerson ?RealPerson2
}
```

Query Results

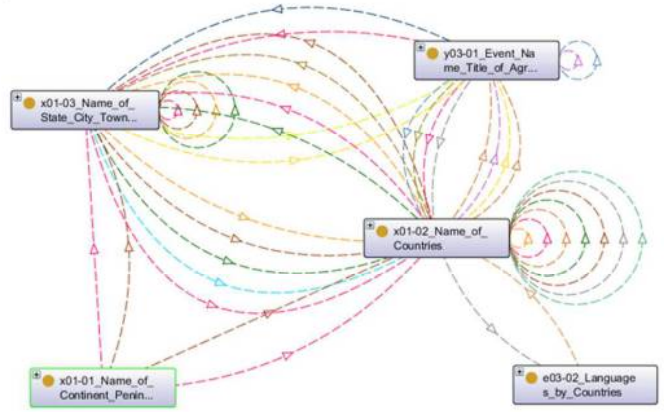
[Real_Person]	[Organization_Name_Group_Name]	{Event_Name_Title_of_Agreement}	[Name_Of_Countries]	[Period]	[Real_Person2]
최남선 (Choi, Namsun)	조선광문회 (Chosun Gwangmunhoe)	시조 부흥 운동 (Sijo Renaissance Campaign)	대한민국 (Republic of Korea)	일제강점기 (Japanese Colonized period)	이병기 (Lee, Byungki)
마오쩌둥 (Mao Zedong)	홍위병 (Red Guards)	문화 대혁명 (The Cultural Revolution)	중국 (China)	중국 현대 (Contemporary China)	김염 (Jin Yan)
마오쩌둥 (Mao Zedong)	홍위병 (Red Guards)	문화 대혁명 (The Cultural Revolution)	중국 (China)	중국 현대 (Contemporary China)	레이펑 (Lei Feng)
스탈린 Stalin, Iosif Vissarionovich)	세계경제세계정치 연구소 (The Institute of World Economics and World Politics)	대숙청 (Great Purge)	소련 (Soviet Union)	서양 현대 (Contemporary Western)	니콜라이 부하린 (Bukharin, Nikolai Ivanovich)
쑨원 (Sun Wen)	중국 국민당 (Guomindang)	신해 혁명 (Xinhai Revolu ion)	중국 (China)	중국 근대 (Modern Times of China)	위안스카이 (Yuan Shikai)

※ Korean word translated into English in brackets.
※ The total number of search results for scenario 5 is 12, and we tabulate just 5 results.

Table 8 Ontology Structure and Query Results of Scenario 6

Scenario 6	[Name_of_Countries] at which [Event_Name_Title_of_Agreement] occurred is located in the [Name_of_Continent_Peninsula], which is adjacent to [Name_of_Countries 2]; its capital is [Name_of_State_City_Town], [Languages_by_Countries] was used.

Ontology Structure



SPARQL Query

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : <http://www.stnet.re.kr/ontology#>

SELECT ?EventName ?Country ?Continent ?Country2 ?Capital ?Language

WHERE {
        ?EventName rdf:type :y03-01_Event_Name_Title_of_Agreement.
        ?Country rdf:type :x01-02_Name_of_Countries.
        ?Continent rdf:type :x01-01_Name_of_Continent_Peninsula.
        ?Capital rdf:type :x01-03_Name_of_State_City_Town_Street_Avenue.
        ?Language rdf:type :e03-02_Languages_by_Countries.
        ?Country2 rdf:type :x01-02_Name_of_Countries.
        ?EventName :hasLocation ?Country.
        ?Country :hasLocation ?Continent.
        ?Country :isAdjacentTo ?Country2.
        ?Country :hasCapital ?Capital.
        ?Country :hasLanguage ?Language.
}
```

Query Results

[Name_of_ Countries]	[Event_Name_Title_of_ Agreement]	[Name_of_ Continent_ Peninsula]	[Name_of_ Countries2]	[Name_of_ State_City_Town]	[Languages_by_ Countries]
이집트 (Egypt)	출애굽 (Exodus)	북아프리카 (North Africa)	리비아 (Libya)	카이로 (Cairo)	아랍어 (Arabic)
프랑스 (France)	테르미도르 반동 (Thermidor coup d'État)	서유럽 (Western Europe)	영국 (United Kingdom)	파리 (Paris)	프랑스어 (French)
프랑스 (France)	68 학생 혁명 (68 Revolution)	서유럽 (Western Europe)	영국 (United Kingdom)	파리 (Paris)	프랑스어 (French)
프랑스 (France)	앵포르멜 (Informel)	서유럽 (Western Europe)	영국 (United Kingdom)	파리 (Paris)	프랑스어 (French)
프랑스 (France)	프로이센 프랑스 전쟁 (Franco-Prussian War)	서유럽 (Western Europe)	영국 (United Kingdom)	파리 (Paris)	프랑스어 (French)

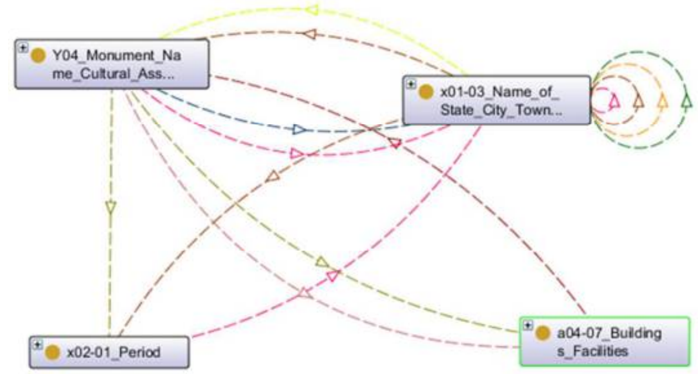
※ Korean word translated into English in brackets.

※ The total number of search results for scenario 6 is 264 and we tabulate just 5 results.

Table 9 Ontology Structure and Query Results of Scenario 7

Scenario 7	The most famous thing in this [Name_of_State_City_Town] is the [Monument_Name_Cultural_Asset_Name] that represents the genre of [Buildings_Facilities], which was produced in the period of [Period].

Ontology Structure



SPARQL Query

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX : http://www.stnet.re.kr/ontology#>

SELECT ?City ?Monument ?Era ?Genre

WHERE {
        ?City rdf:type :x01-03_Name_of_State_City_Town_Street_Avenue.
        ?Monument rdf:type :Y04_Monument_Name_Cultural_Asset_Name.
        ?Era rdf:type :x02-01_Period.
        ?Genre rdf:type :a04-07_Buildings_Facilities.
        ?Monument :hasLocation ?City.
        ?Monument :hasEra ?Era.
        ?Monument :hasGenre ?Genre.
}
```

Query Results

[Name_of_State_City_Town]	[Monument_Name_Cultural_Asset_Name]	[Buildings_Facilities]	[Period]
고양 (Goyang-si)	서삼릉 (Seosamneung Royal Tombs)	왕릉 (Royal Tomb)	조선시대 (Period of Chosun Dynasty)
구리 (Guri-si)	동구릉 (Donggureung Royal Tombs)	왕릉 (Royal Tomb)	조선시대 (Period of Chosun Dynasty)
공주 (Gongju-si)	무령왕릉 석수 (Stone Image of an Animal in the Royal Tomb of King Muryeong)	석수 (Stone Image of an Animal)	백제시대 (Period of Baekje Kingdom)
충청남도 (Chungcheongnam-do)	정림사지오층석탑 (Five storied Stone Pagoda of Jeongnimsa Temple Site)	석탑 (Stone Pagoda)	백제시대 (Period of Baekje Kingdom)
익산 (Iksan-si)	미륵사지 석탑 (Stone Pagoda of Mireuksa Temple Site)	석탑 (Stone Pagoda)	백제시대 (Period of Baekje Kingdom)

※ Korean word translated into English in brackets.
※ The total number of search results for scenario 7 is 84 and we tabulate just 5 results.

5. Discussion

The context of this research is information retrieval utilizing the structural terminology based ontology. A problem with traditional information retrieval systems is that they typically retrieve information without an explicitly defined domain of interest to the user. Consequently, the system presents a lot of information that is of no relevance to the user. Finding relevant and useful information from large collections of research data still poses some significant challenges. In this context, one of the substantial opportunities is to consider the semantics of the information using ontology. The research presented in this paper examines how the structural terminology based ontology can be efficiently utilized for information retrieval systems.

In the recent past, several ontology-based approaches have been proposed. Koopman et al. (2011) illustrates reports on the methods, results and experience using a concept-based information retrieval approach. Jain & Madan (2012) evaluated the document adequacy with respect to a query using semantic proximities between ontology concepts and aggregating models. Sy et al. (2012) presented method for semantic query in out-dated relational database by creating ontological layer. A schema ontology is mined from relational database.

Information retrieval is used to satisfy users' needs for information. In order to achieve this goal, Information retrieval deals with representation, organization of, and access to information. As information retrieval mainly deals with natural language, which might be semantically ambiguous, the user may rather be interested in retrieving information about subject and context.

This paper presented a new methodology for supporting information retrieval within a specific domain using expanded queries based on a novel model of structural terminology based ontology. In our system as shown in table 3 to 9, the user who wants to access the specific topic can create query that brings the semantically relevant information. The search results show the logical combination of semantically related term data, which would be difficult to deduce results via a traditional information retrieval system.

Even if the model has to be intended as a prototype architecture, further improvements can lead to a realistic and effective semantic application for general mining tasks. Moreover, the effective use of the ontology for supporting expanded query is an interesting example of how ontology-based techniques can be successfully exploited in the framework of information retrieval applications. It may emerges that in order to make the use of the ontology effective in real applications, the represented conceptual knowledge must be strictly tied to the lexical knowledge such as STNet.

Specifically, semantic dictionary is necessary for developing the efficient semantic search technology in the field of humanities and social sciences, because a number of contents created in those disciplines contain metaphysical, conceptual, and abstract expressions in the text. Therefore, the utilization of STNet as an index database in retrieval services and the mining of informal big data will raise the efficiency in data refinement and search works through the application of well-defined semantic concepts to each term.

6. Conclusion

This study was conducted to suggest a structural academic glossary as a new knowledge organization structure to overcome the limitations of the existing knowledge structures and to verify the possibility of semantic search applying inference rules based on relationships among terms and the properties of classes in the structural academic glossary database.

We constructed the structural academic glossary database named STNet, targeting author keywords from journal articles published in the fields of the humanities, social sciences, arts, and sports in KCI since September 2013. As of December 31, 2015, there are 55,236 academic terms defined in the STNet database. There are 72,839 data (object type) in 'Object Type Property', 25,984 data (code or text type) in 'Data Type Property', and 209,701 relationships between terms linked by relation predicates.

For the experiment, we analyzed the relation types among the input data and set up all class structures and property types. Then, we verified errors in the basic settings for each class and property using the Pellet inference engine after defining 'Domain' and 'Range'. We confirmed that there were no logical errors in composed ontology structure and converted the STNet RDB data into RDF data via an RDF ontology converter. Then, we verified that the 55,177 terms linking with properties in the 170 classes of STNet database were converted into RDF ontology with 88 'ObjectType Properties' and 40 'DataType Properties' in the STNet.

Furthermore, we generated inference control rules targeting high-input-ratio data in the properties of classes by calculating the input ratio of real input data in the STNet, and then we executed a semantic search by SPARQL query by setting very complicated search scenarios, for which it would be difficult to deduce results via a simple keyword search. As a result, it was confirmed that the search results show the logical combination of semantically related term data.

In addition, because this study was implemented using a bottom-up approach by evaluating semantic search results and developing inference rules based on the structure of the existing RDB-based STNet system, it is different from most previous studies, which used top-down approaches that organized systems after setting up ontology structures and inference rules targeting specific domains.

Appendix A. STNet Taxonomy.

Top level classes	Mid-level classes	Lower level classes: 1st lower level	Lower level classes: 2nd lower level
A_Object	A01_Human	a01-02_Biological_Character	a01-02-01_Gender
			a01-02-02_Age
		a01-03_Human_Relations	a01-03-01_Kinship
			a01-03-02_Personal_Relationship
		a01-04_Social_Group	a01-04-01_Ethnic_Ratial_Group
			a01-04-02_National_Groups
			a01-04-03_Residence_Situation
			a01-04-04_Social_Class
			a01-04-05_Generation
			a01-04-06_Community
			a01-04-07_Family_Name
		a01-05_ People_with_Ability_Tendency	a01-05-01_Gifted_People
			a01-05-02_ People_with_Disabilities_Illnesses
			a01-05-03_People_with_Tendency
		a01-06_Occupation_Status_Role	a01-06-01_Occupation
			a01-06-02_Status_Government_Post
			a01-06-03_Role
		a01-07_Semi-Human	
		a01-08_Physical_Body	a01-08-01_Body_Organs
			a01-08-02_Substance
			a01-08-03_Disorders_Diseases
	A02_Institution_Organization	a02-01_Administrative_Agency_Public_Institution	
		a02-02_Educational_Institution	
		a02-03_Enterprise_Company	
		a02-04_Social_Religious_Organization_Group	
	A03_Natural_Object	a03-01_Animals	
		a03-02_Plants	
		a03-03_Nature_Mineral	
	A04_Artifacts	a04-01_Goods_Products	
		a04-02_Materials_Components	
		a04-03_Teaching_Materials	
		a04-04_Clothes	
		a04-05_Groceries	
		a04-06_Tools_Machines	
		a04-07_Buildings_Facilities	
		a04-08_Transportation	
		a04-09_Creative_Works_Information	
B_Action /Function	B01_Action_Activity_Role	b01-01_Action_Activity	
		b01-02_Educational_Activity	
		b01-03_Economic_Industrial_Activity	
		b01-04_Illigal_Act	
		b01-05_Physical_Activity_Action	
		b01-06_Fuction_Role	
	B02_Change	b02-01_Relaxation_Decrease_Reduction_Decline	
		b02-02_Reinforcement_Increase_Extension_Expansion	
		b02-03_Reformation_Reorganization_Rearrangement_Innovation	
		b02-04_Transition_Process	
		b02-05_Decomposition_Integration	
C_Property	C01_Characteristic_Property	c01-01_Tendency_Trend	
		c01-02_Disposition_Quality_Character_Propensity	
		c01-03_Level_Degree	

		c01-04_Ability_Power_Energy	
		c01-05_Distribution	
		c01-06_Environment	
		c01-07_Sense	
	C02_Psychology	c02-01_Emotion	
		c02-02_Cognition_Consciousness	
	C03_Phenomenon_Issue	c03-01_Condition_Situation	
		c03-02_Gap_Difference	
		c03-03_Culture_Life	
		c03-04_Economy_Management_Trade	
		c03-05_Politics_International_Issues	
D_Theory /Method	D01_Theory_Thought_ Ideology_Principle_Rule	d01-01_Theory_Thought	
		d01-02_Principle_Rule	
		d01-03_Academic_Discipline	
		d01-04_Concept_Definition	
	D02_System	d02-01_Social_System	
		d02-02_Political_System_Legal_System	
		d02-03_Economic_System_Management_System	
	D03_Method	d03-01_Research_Investigation_Method	
		d03-02_Analysis_Method	
		d03-03_Measurement_Scale	
		d03-04_Index_Indicator	
	D04_Technique_Strategy	d04-01_Technique_Way	
		d04-02_Evaluation_Analysis	
		d04-03_Teaching_Learning_Method	
		d04-04_Strategy_Tactics	
E_Format /Framework	E01_Form_Type_Style_Genre	e01-01_Literature_Genre	
		e01-02_Music_Genre	
		e01-03_Genre_of_Fine_Art_Design	
		e01-04_Type_of_Sports_Recreations	
		e01-05_Performing_Art	
	E02_Model_Criteria	e02-01_Model	
		e02-02_Pattern	
		e02-03_Criteria_Regulation_Qualification	
		e02-04_Standard	
		e02-05_Infrastructure_Structure_Scope	
		e02-06_Symbol_Sign	
	E03_Languages	e03-01_Language_Letter	
		e03-02_Languages_by_Countries	
	E04_Space	e04-01_Artificial_Space	
		e04-02_Ideological_Space	
		e04-03_Natural_Space	
X_General /Common	X01_Place_Name	x01-01_Name_of_Continent_Peninsula	
		x01-02_Name_of_Countries	
		x01-03_Name_of_State_City_Town_Street_Avenue	
		x01-04_Name_of_Mountains	
		x01-05_Name_of_Ocean_River_Lake	
		x01-06_Name_of_Constellation_Astronomical_Phenomena	
	X02_Period_Time	x02-01_Period	
		x02-02_Term	
		x02-03_Time	
	X03_Relationship_Interaction	x03-01_Origin_Derivation	
		x03-02_Comparison_Distinction	
		x03-03_Class_Grade_Line	
		x03-05_Cause_and_Effect	x03-05-01_Cause_Condition_Element
			x03-05-02_Result
			x03-05-03_Effect_Impact

		x03-06_Interaction	x03-06-01_Combination_Union_Alliance
			x03-06-02_ Exchange_Interchange_Relationship
			x03-06-03_Participation_Arbitration
			x03-06-04_Response_Correspondance
			x03-06-05_ Inverse_Opposition_Argument_Struggle
Y_Instance	Y01_Persons_Name	y01-01_Real_Person	
		y01-02_Virtual_Person	
	Y02_Title_of_Creative_Work	y02-01_Title_of_Literature	
		y02-02_Title_of_Works	
		y02-03_Title_of_Newspaper_Magazine	
		y02-04_Title_of_Broadcast_Program	
		y02-05_Title_of_Map	
		y02-06_Title_of_Document	
	Y03_Event_Name	y03-01_Event_Name_Title_of_Agreement	
		y03-02_Name_of_National_Holiday_Name_of_Anniversary	
		y03-03_Name_of_Ceremony_Name_of_Festival	
		y03-04_Name_of_Award	
	Y04_Monument_Name_Cultural_Asset_Name		
	Y05_Name_of_Law_Name_ of_System	y05-01_Name_of_Law_Legislation	
		y05-02_Name_of_Treaty_Name_of_Agreement	
		y05-03_Name_of_Policy_Name_of_System	
	Y06_Institution_Name_ Organization_Name	y06-01_Organization_Name_Group_Name	
		y06-02_Name_of_Government_Dynasty	
		y06-03_Name_of_School_Name_of_Denomination	
		y06-04_Name_of_Meeting	
	Y07_Product_Name	y07-01_Name_of_Instrument_Tool	
		y07-02_Product_Name_Brand_Name	
		y07-03_Name_of_Building_Name_of_Facility	

Appendix B. STNet Relation Predicates.

Classification		The Name of Relation	The Name of Inverse Relation
Equivalent Relationship	Synonym	UF	USE
	Prior & Later name	PT	LT
Hierarchical Relationship	Subordinate	NT	BT
		hasKind	isKindOf
	Whole-Part	hasBranch	isBranchOf
		hasComponent	isComponentOf
		hasMember	isMemberOf
		containsSubstance	isSubstanceOf
		hasIngredient	isIngredientOf
		spatiallyIncludes	isSpatiallyIncludedIn
	Concept-Instance	hasInstance	isInstanceOf
Associative Relationship	Conceptual	RT	
		RT_X	RT_Y
		hasIssue	isIssueIn
		isConceptuallyRelatedTo	isConceptOf
		hasPhenomenon	isPhenomenonOf
		basesOn	isBaseFor
		affects	isAffectedBy
		hasProperty	isPropertyOf
		hasPurpose	isPurposeOf
		hasResult	isCausedBy
		hasSubject	isSubjectIn
		originatesFrom	isOriginOf
		hasProcess	isProcessOf
		hasPatient	hasAgent
		hasState	isStateOf
		hasDegree	isDegreeOf
		isTributaryOf	hasTributary
	Functional	applys	isAppliedTo
		hasOpposition	isOppositionOf
		hasMeasurement	isMeasurementOf
		manages	isManagedBy
		analyzes	isAnalyzedBy
		evaluates	isEvaluatedBy
		hasMethod	isMethodOf
		produces	isProducedBy
		hasSolution	isSolutionFor
		hasReplacement	isReplacementOf
		hasSupplement	isSupplementOf
		advocates	isAdvocatedBy
		hasFounder	isFounderOf
		hasWork	hasCreator
	Temporal	precedes	succeedes
		co-occursWith	
		hasEra	-
	Spatial	isAdjacentTo	
		surrounds	isSurroundedBy
		traverses	isTraversedBy
		hasLocation	-
	Physical	hasForm	isFormOf
		isConnectedTo	
	Antonym	hasAntonym	

※ All 'Associative Relationships' can map with all properties of the STNet classes. We created separate names for properties in the form of 'relation predicates' if it was difficult to express the concrete meaning by 'relation predicates' in the table above. For example, if 'hasLocation' would be used for properties to express the birthplace or the nationality, it was difficult to separate the exact meaning. In this case, we created 'hasBirthPlace' and 'hasNationality' separately.

※ The 170 classes in the STNet have many more properties than can be discussed in this paper.

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