

Semantic Web Ontologies Pertaining to Heterogeneity and Social Networks

Daniela Martignani, Peter Miele, and Jennifer Shaska

Abstract—In this paper we will summarize three current documents on how ontologies can be used to navigate and combine social networks to facilitate decisions on which meaning or instance of a concept a user wants to see. A common problem amongst this domain is linking concepts between ontologies if those ontologies use different semantics for the same concept or the same semantics for different concepts, techniques are evolving to solve this problem. We will also cover a summary of various ontology description languages and how they interact in semantic web for various uses. These techniques and ontology languages can be used when querying social networks to find relations to narrow the search down to those that are relevant to the current user.

Index Terms—Ambiguity, Ontology, Redundancy, Semantic Web, Social Network,



1 INTRODUCTION

THE semantic web is a means of using the world wide web to create a method of sharing data between computers so that a machine can query and infer knowledge from existing information. In this paper we will cover three existing sources of information on the semantic web.

Currently the web is not organized in a manner in which information can be processed easily by a machine; instead it is structured to be utilized by humans who can parse and extract information that is presented in an unorganized manner. Semantic web provides a means of organization that structures information in a simple format that can easily be parsed and utilized by a machine to handle user queries, and create inferences based on formal logic systems.

Sections 2.1 and 2.2 will cover the data format of the semantic web and why it is structured the way it is in comparison to well-known formats. This will cover the Resource Description Framework (RDF), the Resource Description Framework schema (RDFS), and the Web Ontology Language (OWL) and how they relate to well-known data formats like EXtensible Markup Language (XML), Unified Modeling Language (UML), and Entity/Relation Modeling (E/R Modeling) of databases. This background and conceptual overview will provide a basis for understanding the underlying concepts of the semantic web so that their application can be appreciated.

Section 2.3 will cover the notions of the issues of independent actors all trying to author and use the semantic web at once with no over-arching governing body. This will go over the problem of multiple resources having the same identifier, called semantic ambiguity. We will also cover the issue of multiple authors all authoring the same resource which means query processor has to find the correct one which is semantic redundancy. Their findings indicate that you can, at better than chance rate, determine the correct

resource to use when performing a search using an ambiguous term and relate that term across different ontologies.

Section 2.4 will review a paper that applies some of these concepts in the realm of social media and connecting users across social networks. This paper addresses the issue of social networks not being able to interconnect amongst the web of all social networks. This is due to the ever changing landscape of social media content and the lack of a framework that successfully integrates the different ontologies to relate all the users and content. They presented an overview of existing ontologies, such as Friend-of-a-Friend (FOAF), Semantically Interlinked Online Communities (SIOC), Simple Knowledge Organization System (SKOS), and Dublin Core (DC) and how these ontologies can be used together to build a framework and address the issue of creating a more interconnected web. A brief discussion is included of how this framework will help describe user generated content on social networks and how it relates to users.

2 REVIEWS OF DOCUMENTS

2.1 Social networks and the semantic web [1]

The current version of the web contains lots of unstructured data which is easily understood by humans but not easily understood by machines. People are naturally able to process this data due to our ability to infer new ideas based on ideas we already know, and our ability to make connections between somewhat unrelated topics. The main goal of the Semantic Web is to have structured data which machines can programmatically process to make some of the same connections that human readers naturally make. So we need formal languages which machines can use to interpret data and make connections between resources available throughout the web.

This need for formal languages is not unique to the Semantic Web. Several areas have strong foundations in formal or semi-formal reasoning. Some that are familiar to people in the computer science field are artificial intelligence, software modelling, and database design.

• Authors are graduate students in the Department of Computer Science and Engineering, Oakland University, Rochester, MI, 48309.

• dmartign@oakland.edu, pamiele@oakland.edu, jlshaska@oakland.edu

Manuscript submitted April 7, 2016

Artificial intelligence experts have been studying the representation of knowledge for a long time. One focus has been on separating domain knowledge from task knowledge. Domain knowledge means understanding information about the system, while task knowledge means understanding how to solve a problem in the system. Paper [1] gave some good examples about how having either of these kinds of knowledge in one system can be useful in another system. A domain knowledge of human anatomy can obviously be used in more than one diagnostic system (say, cancer diagnosis and the diagnosis of stomach ailments). And a task knowledge of how to choose the right medical diagnosis given a list of symptoms can be carried over to be used in the diagnosis of car engine problems. Logic-based knowledge representation languages have been developed to describe both domain knowledge and task knowledge. Agreement of some standards has increased reusability. For a given domain, knowledge engineers have techniques to elicit knowledge from domain experts which they then formalize into logic-based representations.

Software engineering also uses somewhat formal languages to model information about a system in a visual way, so that ambiguity can be minimized and team members can agree on the design details of a system. UML has become popular because it helps a team member to interpret a system in the same way that the other team members do, and is a powerful aid for specifying requirements and creating designs.

Similarly, in database design, Entity/Relationship models have helped bring order and cohesive thought in the process of creating and extending databases. Both UML and E/R models help achieve interoperability between applications because of standardization. In order for them to be useful, team members must agree on terms and relationships in the domain.

An ontology is a domain model which uses formal language to capture the information and relations in a system. Semantic Web uses ontologies to add knowledge about domains. Ontologies existed before the Semantic Web existed, but because of the Semantic Web, new languages were developed. While UML and E/R models are used to model enclosed systems, Semantic Web is trying to model and connect knowledge across the entire web, so new languages were necessary. Two such new languages were RDF and OWL. These two languages are grounded in formal logic, so computer scientists tend to be less comfortable with them than they are with UML, E/R model languages, and XML. But RDF and OWL do have some similarities to these languages, in that they are all based on objects, properties, and values.

One of the main requirements for a domain model to be considered an ontology is that it must be expressed in a formal language with a well-defined semantics. RDF and OWL meet this requirement and they are the most common ontology languages used for Semantic Web.

The Semantic web will be a network of ontologies, with semantics added to web content (like Web resources and databases) which can be processed by machines. The ontology languages used by the Semantic Web identify concepts in ontologies by using Uniform Resource Identifiers (URIs). The URIs point to concepts and relationships in other re-

mote, public ontologies. So the various ontologies will be linked across the web, similar to how hyperlinks in web pages form a linked network across the web.

The data and schema of an ontology can be publicized by publishing an RDF or OWL document online or by providing access through SPARQL, a standard query language and protocol of the Semantic Web. To annotate Web content or to publish the content of a database, a new ontology can be created or an existing ontology can be extended. Formality and detailedness of ontologies are important for computers to be able to mimic the way humans capture the meanings of concepts and relationships.

RDF and OWL have been standardized by the World Wide Web Consortium in recent years. Although RDF was created just to be able to describe resources on the web, it is domain-independent and can be used to model real-world objects and resources. It is a primitive modelling language, and it forms the basis of more complex languages like OWL.

2.1.1 RDF

RDF has two kinds of primitives: resources and literals. Resources are purposely defined vaguely; anything that could be identified and described can be a resource. Resources can be identified with a URI, or the identifier can be left blank. Literals are strings, which may or may not have language and datatype identifiers. Figure 1 shows some RDF vocabulary.

Basic constructs	<i>rdf:type</i> <i>rdf:Property</i> <i>rdf:XMLLiteral</i>
Collections	<i>rdf:List</i> <i>rdf:Seq</i> <i>rdf:Bag</i> <i>rdf:Alt</i> <i>rdf:first</i> <i>rdf:rest</i> <i>rdf:nil</i> <i>rdf:n</i>
Reification	<i>rdf:value</i> <i>rdf:Statement</i> <i>rdf:subject</i> <i>rdf:predicate</i> <i>rdf:object</i>

Figure 1: The RDF Vocabulary, from [1].

RDF statements consist of triples of the form (subject, predicate, object). The subject is a resource, either with a URI identifier or a blank identifier. The predicate is a URI, and the object is either a resource or a literal. Figures 2 and 3 show an example very similar to one in [1] of an RDF document describing a person named Washington:

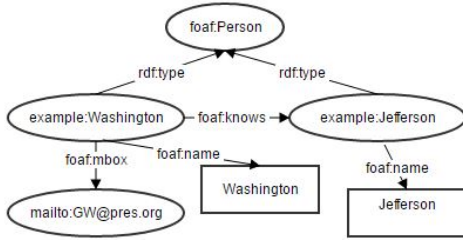


Figure 2: Example similar to one in [1].

```
@prefix rdfs: <http://www.w3.org/2000/01/rdf-
schema#label>.
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-
syntax-ns>.
@prefix ex: <http://www.example.org/>.
@prefix foaf: <http://xmlns.com/foaf/0.1/>.
```

```
ex:Washington rdf:type foaf:Person .
ex:Jefferson rdf:type foaf:Person .
ex:Washington foaf:name "Washington" .
ex:Washington foaf:knows example:Jefferson .
ex:Washington foaf:mbox <mailto:GW@pres.org>.
ex:Jefferson foaf:name "Jefferson" .
```

Figure 3: Example similar to one in [1].

This example refers to the Friend-of-a-Friend (FOAF) ontology, which is an RDF document on the Web which defines some of the terms used in the example (see [2]). Figure 4 shows some of the FOAF vocabulary.

```
@prefix foaf: <http://xmlns.com/foaf/0.1/> .

foaf:Person rdf:type owl:Class .
foaf:Person rdfs:label "Person" .
foaf:Person rdfs:subClassOf foaf:Agent .
foaf:Person owl:disjointWith foaf:Document .

foaf:knows rdf:type owl:ObjectProperty .
foaf:knows rdfs:label "knows" .
foaf:knows rdfs:domain foaf:Person .
foaf:knows rdfs:range foaf:Person .

foaf:name rdf:type owl:DatatypeProperty .
foaf:name rdfs:label "name" .
foaf:name rdfs:subPropertyOf rdfs:label .
foaf:name rdfs:domain owl:Thing .
foaf:name rdfs:range rdfs:Literal .
```

Figure 4: Some statements from the FOAF ontology about the terms used in the previous example, taken from [1].

RDF Schema (RDFs) extends RDF, by including the notion of classes and subclasses. Domains and ranges of properties are used to connect classes and properties. Many times RDF and RDFs are referred to interchangeably. Some RDFs vocabulary is shown in Figure 5.

RDF(s) uses model-theory semantics, where meaning is defined by mappings from a model to a meta-model in which the truth of propositions is already uniquely determined. This kind of mapping is called an interpretation, where symbols are mapped to the objects or relations they are describing. Constructs are used to put constraints on possible interpretations, so that unintended interpretations

Basic constructs	<i>rdfs:domain</i> <i>rdfs:range</i> <i>rdfs:Resource</i> <i>rdfs:Literal</i> <i>rdfs:Datatype</i> <i>rdfs:Class</i> <i>rdfs:subClassOf</i> <i>rdfs:subPropertyOf</i>
Collections	<i>rdfs:member</i> <i>rdfs:Container</i> <i>rdfs:ContainerMembershipProperty</i>
Documentation & reference	<i>rdfs:comment</i> <i>rdfs:seeAlso</i> <i>rdfs:isDefinedBy</i> <i>rdfs:label</i>

Figure 5: The RDF Schema Vocabulary, taken from [1]

are excluded. For example, we can use a construct to not allow two symbols used to represent persons to be mapped to the same person. RDF(s) also allows some axiomatic triples that are true for every model interpretation. For example, *rdfs:subPropertyOf* follows the rules shown in Figure 6.

$$\begin{aligned}
 &(aaa, rdfs:subPropertyOf, bbb) \wedge (bbb, rdfs:subPropertyOf, ccc) \\
 &\rightarrow (aaa, rdfs:subPropertyOf, ccc) \\
 &(aaa, rdfs:subPropertyOf, bbb) \rightarrow (aaa, rdf:type, rdf:Property) \\
 &(aaa, rdfs:subPropertyOf, bbb) \rightarrow (bbb, rdf:type, rdf:Property) \\
 &(xxx, aaa, yyy) \wedge (aaa, rdfs:subPropertyOf, bbb) \rightarrow (xxx, bbb, yyy)
 \end{aligned}$$

Figure 6: Example of *rdfs:subPropertyOf* Rules, from [1]

An important part of RDF semantics is that interpretations are assumed to be open world and monotonic. An open world assumption means that we can never assume that we have a complete description of the world. The fact that we have a document describing a certain resource does not imply that we know everything about that resource. Monotonicity means that new knowledge added is not allowed to make previous references invalid. As an example, if the range of the *foaf:knows* property is *Person*, and we know that a person named Frank knows a dog named Pluto, we don't take it as a contradiction. Instead, we assume that there exists some other statement that defines the *Dog* class to also be in the range of *foaf:knows*. That is, statements about an RDF resource only give additional information about that resource and do not invalidate or contradict things previously known about the resource.

2.1.2 OWL

OWL (Web Ontology Language) adds constructs of Description Logics to RDF, which allow for greater expressiveness in characterizing classes and properties. OWL is really a set of three languages with increasing expressiveness: OWL Lite is a subset of OWL DL which is in turn a subset of OWL Full. The additional expressivity provided by OWL is used for modelling complex domains like medicine and engineering.

2.2 Comparison to Other Formats Commonly Used in Computer Science Domain

2.2.1 Comparison to UML

There is quite a bit of overlap between UML and RDF/OWL. But UML has a smaller scope because its primitives are for a certain kind of information resource: objects

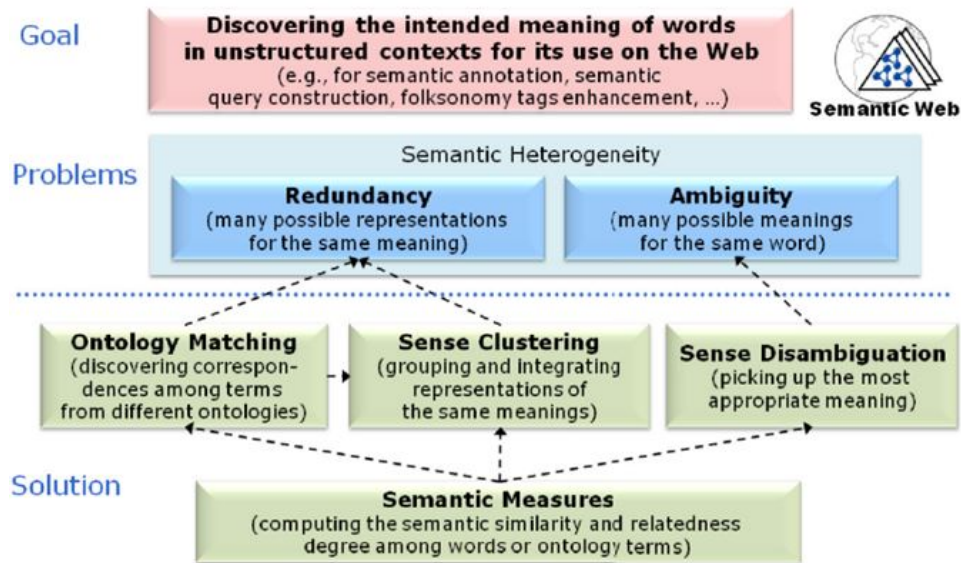


Figure 7: Dealing with Semantic Heterogeneity, from [3]

and their roles in an OO system. So RDF/OWL modelling is less constrained than UML modelling and provides primitives not found in UML, such as the disjointness, union, intersection, and equivalence of classes.

Also, in RDF/OWL, properties are global, and they don't belong to a class like attributes and associations belong to a certain class in UML. And non-blank resources in RDF are identified with a URI while UML classes, instances, attributes, etc., don't have such an ID. And the closed world assumption of UML is of course different from the open world assumption of RDF/OWL. There are tools available to convert UML class models into OWL ontologies.

2.2.2 Comparison to E/R Model

Entity/Relationship modelling is used to model the relations between data structures in database management systems, and is considered as being much simpler than UML. Entity sets in E/R modelling are roughly like classes in UML. But in E/R, the only predefined relationship is generalization, which only refers to attribute inheritance; in E/R models, generalization between relationships (ex: subPropertyOf) is not allowed as it is in RDF.

A useful feature in E/R is the ability to identify keys. Keys from E/R models can be replicated in RDF/OWL, but composite keys can not. One advantage that RDF has over E/R modelling is that it gives every resource an identifier, even for resources which are not fully described. But this disadvantage in E/R modelling can be easily resolved, by creating new primary keys in each entity by making a new column with a unique identifier.

Because many organizations are financially entrenched in their relational databases, it is desirable to keep their data in a RDBMS and map it to a publishable ontology, but this can be difficult in practice.

2.2.3 Comparison to XML

XML and RDF are similar in many aspects. XML has directed, ordered trees and RDF has directed graphs. Both XML and RDF are conceptual models having domain specific languages providing their own vocabularies. But XML is used for representing hierarchical data, with nested, ordered elements. RDF has a stricter model to represent arbitrary directed graphs with edges representing relationships between classes or instances of classes. Since there are so many connections between concepts in domain models, hierarchical representations are not sufficient. While XML has a natural ordering of elements, RDF allows properties to be listed in unconstrained orders.

2.3 Dealing with Semantic Heterogeneity Issues on the Web [3]

When working with ontologies, a major concern in the semantic web, there is a hurdle to overcome with the decentralized definition of ontologies. Each individual or organization can define ontologies on their own with no oversight by a central body. This means that the same concept that is defined in one ontology can be defined again in another ontology and may even be defined differently. Another case is that two different ontologies use the same terminology for differing concepts. These two scenarios are defined by Gracia and Mena ([3]) as:

Semantic Ambiguity: many intended meanings are associated with the same word.

Semantic Redundancy: many semantic descriptions are available to represent the same intended meaning.

An example of this problem is trying to determine the meaning of the word "apple" in a query such as "Give me a list, ordered by calories, of recipes containing apple". In the example query the term "apple" is likely apparent to

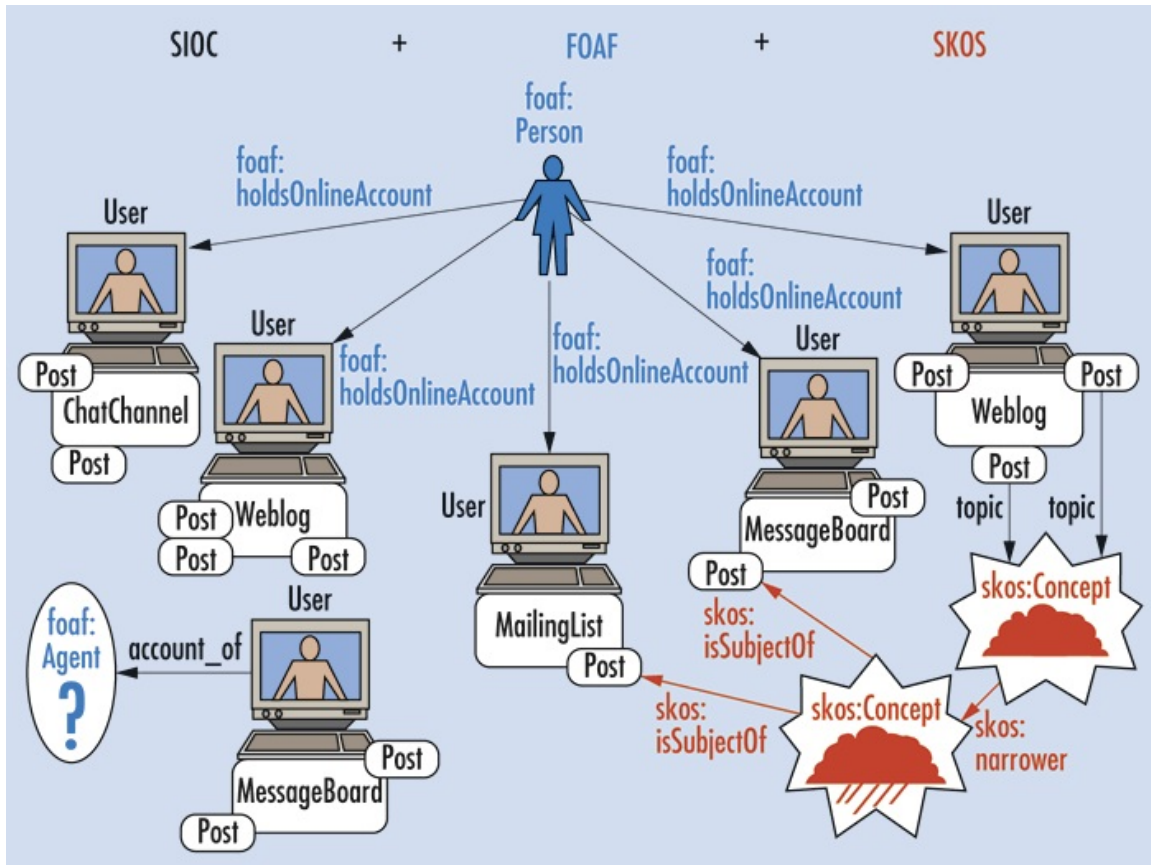


Figure 8: Relationships between Ontologies [4]

a human reader, but to a device trying to determine the semantics of the word it can be difficult. If "apple" is run through an ontology it might come back with three results, apple the fruit, apple the tree, and Apple the corporation. With these three results the query processor needs to determine what concept represented by "apple" does the user want to obtain in the results.

In order to find the correct concept, a search may cross many ontologies where each may have a definition of apple and its related concepts. This is where semantic ambiguity and redundancy start to have an effect. In order to filter the search down to likely candidates, word sense disambiguation techniques can be used.

There are first techniques to reduce semantic heterogeneity of the result set. There are three techniques proposed by Gracia and Mena ([3]) for accomplishing semantic heterogeneity reduction. In ontology matching, a set of terms are compared to each other based on context and the relations that don't meet a threshold are removed. The output of ontology matching then is fed into sense clustering.

In sense clustering the relatedness of two concepts that share keywords are used to determine if the two concepts should be integrated into a single concept. When two concepts are merged together, then the ontology matching algorithm needs to be run again to calculate the similarities of the new integrated concept.

After sense clustering comes sense disambiguation, in which the concept that the user is trying to query on is determined from the context of the query and the clusters created from sense clustering. This is done by taking the inputted query and breaking it down into keywords and context words to be utilized for the disambiguation and then searching through related concepts in order to find the best fitting one. The first step is to break down the query into individual words and select a keyword and then compute the relatedness of each word to the selected keyword. This works on the assumption that the context with the highest relatedness value is the most likely candidate. The relatedness calculation can be done using something like Normalized Google Distance. With a selected context, the clusters from sense clustering are then weighted within the context to find the likely concept that should be used. The final selection can be done by calculating relatedness, number of word overlaps between concept and context, and determining frequency of appearance of the concept in the context overall. Figure 7 shows a general picture of the authors' ideas.

2.4 Using Semantic Web Ontologies for better interoperability on social network sites [4]

The paper summarized in this section aims at introducing all existing ontologies for semantic web, along with their properties and use in a way to provide a basis for a frame-

URL	Definition
skos:Concept	A SKOS concept can be viewed as an idea or notion, a unit of thought.
skos:ConceptScheme	A SKOS concept scheme can be viewed as an aggregation of one or more SKOS concepts. The notion of a concept scheme is useful when dealing with data from an unknown source, and when dealing with data that describes two or more knowledge organization systems.
skos:inScheme	
skos:hasTopConcept	
skos:topConceptOf	
skos:altLabel	A lexical label is a string of UNICODE characters in a given natural language, such as English. SKOS provides some basic vocabulary for associating lexical labels with resources of any type. In particular, SKOS enables a distinction to be made between the preferred alternative and "hidden" lexical labels for any given resource.
skos:	
skos:prefLabel	
skos:notation	A notation is a string of characters such as "TS8.5" used to uniquely identify a concept within the scope of a given concept scheme.
skos:changeNote	Notes are used to provide information relating to SKOS concepts. There is no restriction on the nature of this information, e.g. it could be plain text, hypertext, or an image; it could be a definition, information about the scope of a concept, editorial information, or any other type of information.
skos:definition	
skos:editorialNote	
skos:example	
skos:historyNote	
skos:note	
skos:scopeNote	
skos:broader	SKOS semantic relations are links between SKOS concepts, where the link is inherent in the meaning of the linked concepts. SKOS distinguishes between two basic categories of semantic relation: hierarchical and associative. A hierarchical link between two concepts indicates that one is in some way more general ("broader") than the other ("narrower"). An associative link between two concepts indicates that the two are inherently "related", but that one is not in any way more general than the other.
skos:broaderTransitive	
skos:narrower	
skos:narrowerTransitive	
skos:related	
skos:semanticRelation	SKOS concept collections are labeled and/or ordered groups of SKOS concepts. Collections are useful when a group of concepts shares something in common, and it is convenient to group them under a common label, or where some concepts can be placed in a meaningful order.
skos:Collection	
skos:OrderedCollection	
skos:member	
skos:memberList	The SKOS mapping properties are skos:closeMatch, skos:exactMatch, skos:broadMatch, skos:narrowMatch and skos:relatedMatch. These properties are used to state mapping (alignment) links between SKOS concepts in different concept schemes, where the links are inherent in the meaning of the linked concepts. The properties skos:broadMatch and skos:narrowMatch are used to state a hierarchical mapping link between two concepts. The property skos:relatedMatch is used to state an associative mapping link between two concepts. The property skos:closeMatch is used to link two concepts that are sufficiently similar that they can be used interchangeably in some information retrieval applications. In order to avoid the possibility of "compound errors" when combining mappings across more than two concept schemes, skos:closeMatch is not declared to be a transitive property. The property skos:exactMatch is used to link two concepts, indicating a high degree of confidence that the concepts can be used interchangeably across a wide range of information retrieval applications. skos:exactMatch is a transitive property and it is a sub-property of skos:closeMatch.
skos:broadMatch	
skos:closeMatch	
skos:exactMatch	
skos:mappingRelation	
skos:narrowMatch	
skos:relatedMatch	

TABLE I. SKOS Classes and Properties

work to guarantee inter-operability among multiple social network sites and attain inter-linking of such sites.

2.4.1 Problem Introduction

The authors claim that currently, there are not any established framework that aggregate ontologies. For social networks, which are considered to be "online networks which indicate connections between actors in social activities" [4], some interoperability has been reached by the use of ontologies, but no efforts have been done in inter-linking different social network sites. Because of their current isolation, there is a need to expand the potential such networks offer and find new ways of using ontologies to build a better social network environment that could bring forward more relationships among user-generated content in such sites. The studies of semantic web over the years have not proved successful in extracting relationships and integrating social network sites, so the authors propose a framework to be used to address the issue.

The main challenge of social networks is their inherent nature and the fact that multiple accounts could likely exist for the same user. Furthermore, because of data inconsistency, it is difficult to implement inter-operability and it is also difficult to link multiple social network accounts. Semantic Web was introduced as a technology to make social web sites more connected and to gain more interoperability through metadata creation and inter-connected vocabularies. Existing semantic web vocabulary frameworks such as SIOC (Semantically Interlinked Online Communities) and

FOAF (Friend of-a-Friend) could help on this; hence the authors explain multiple vocabularies could be used together to build a good interoperability framework.

As an example of their use, the authors explain a likely scenario, saying that "SIOC ontology uses FOAF vocabulary to explore a persons attributes, and DC (Dublin Core) vocabulary to illustrate SIOC content properties" [4]. The paper goes on presenting and describing the most dominant and practical ontologies in existence for Semantic Web and how they can be combined to help build an exhaustive framework for social networks; hence proposing a possible solution to the problem.

2.4.2 Literature Review

Given the previous definition of social networks, we can see what the impact of using a semantic network can be. According to the authors, "a semantic network is conceptually a group of entities that are connected through their relationship" [4]. This kind of network provides useful information about individual users that could be used to extract relationships between social network sites. Plainly said, "Semantic Web is the use of new technologies and standards which allow data interpretation and information processing on the World Wide Web" [4]. Technologies such as RDF (Resource Description Framework) and OWL, can be used in Semantic Web for this purpose. Acquiring related data from social network sites has been challenging, because of the intense amount of data and its varying nature. However, Semantic Web and its technologies such as ontologies and

Class	Properties
foaf:Agent	gender yahooChatID account birthday icqChatID aimChatID jabberID made mbox interest tipjar skypeID topic interest age mbox sha1sum status msnChatID openid holdsAccount weblog
foaf:Group	Member
foaf:Organization	Subclass Of Agent Disjoint with: Person, Document
foaf:Person	plan surname geekcode pastProject lastName family_name publications currentProject familyName firstName workInfoHomepage myersBriggs schoolHomepage img workplaceHomepage knows
foaf:Document	topic primaryTopic sha1
foaf:Image	depicts thumbnail
foaf:OnlineAccount	accountName accountServiceHomepage
foaf:PersonalProfileDocument	Status: testing Subclass Of Document
foaf:Project	Status: testing Disjoint With: Person, Document
foaf:LabelProperty	Status: unstable
foaf:OnlineChatAccount	Status: unstable Subclass Of Online Account
foaf:OnlineEcommerceAccount	Status: unstable Subclass Of Online Account
foaf:OnlineGamingAccount	Status: unstable Subclass Of Online Account

TABLE II. FOAF Classes and Properties

vocabularies have methods for better data presentation and provide the ability for machines to automatically originate data from the web, which is an improvement made possible through these new technologies.

Ontologies are "tools to analyze and extract relationships among web sites" [4] since as the authors explain, ontologies can "describe the meaning of a formal vocabulary, identify knowledge within the vocabulary and extract semantics from interconnections on the web" [4]. This capability makes them extremely useful for Semantic Web: they can discover and categorize relationships that exist and delineate relationships between terms within the documents or files that form the Semantic Web Services.

The four main ontologies and vocabularies extensively employed on the web which are explained in the paper are presented in the list below, the way the authors described them:

- Dublin Core (DC): It is explained in the paper as a system combining fifteen elements that are used to describe resources. This set of elements assists the search and information retrieval by capturing basic descriptive categories on the web. DC characteristics are: simplicity of creation and maintenance, interoperability among collections and indexing systems, international applicability, extensibility and modularity. These characteristics allow for compiling metadata and creating a more elaborated description for data resources.
- Friend of a Friend (FOAF): It is mentioned in the paper that this ontology has been built on top of a RDF based schema to "semantically express individuals and their social networks" [4].
- Semantically-Interlinked Online Communities (SIOC): It is mentioned to be a Semantic Web technology which has methods that enable interconnection between social network sites (such as Blogs, forums and others). This ontology is an open-standard machine readable format to extract metadata useful for semantic browsing, content management and social web.
- Simple Knowledge Organization System (SKOS): As expressed in the paper, it is a set of characteristics that provide a standard over RDF documents' vocabularies. Because SKOS can capture organizational knowledge provided in RDF documents, extract similarities and enable technology and information sharing among organization systems, it can be regarded as a "data model to interlink organization knowledge and facilitate knowledge sharing through the web" [4].

Based on the classes and properties related to each ontology, the authors explain that such ontologies can prove to be useful for extracting relationships among diverse social network sites and thus aid in the goal of the paper. Hence, it is the authors' claim that ontologies such as SIOC, FOAF and DC can be combined with other ontologies such as SKOS to obtain more relationships and create a more semantic web.

The classes and properties of each mentioned ontology are shown in TABLE I, TABLE II, TABLE III, and TABLE IV. These tables were taken from the original paper, as well as complemented using sources [5], [2], [6], and [7].

2.4.3 Relationships Among the Ontologies

Figure 8 also shows the relationships between the four ontologies and it helps explain how to create a framework using them. FOAF documents can be used to describe personal information of social network profiles, which can be enhanced by the use of DCs elements that in turn would help describe the users information more meaningfully. Then, the SIOC ontology can be used to map its classes and properties that describe activities in online social community sites to existing vocabularies such as FOAF, RSS and SKOS. The authors use a common example to illustrate these relationships, saying that the property foaf:Person describes a person who also happens to have different online accounts. Then, the sioc:User class defines the same person on different online community sites. This person/user can create any content on his/her sites by using sioc:Item or post content by using sioc:Post. They are related since the

Class	Properties
sioc:Community	Community is a high-level concept that defines an online community and what it consists of. A Community may consist of different types of objects (people, sites, etc.) joined by a common topic, interests or goals. A Community is different from a Site: a Site describes a single community site whilst a Community can consist of a number of Sites and other resources described in SIOC or other ontologies (e.g., FOAF). Community is linked to its constituent parts using the property dcterms:hasPart.
sioc:Container	An area in which content Items are contained. in-range-of: sioc:has_container sioc:has_parent sioc:owner_of sioc:parent_of sioc:subscriber_of in-domain-of: sioc:container_of sioc:has_owner sioc:has_parent sioc:has_subscriber sioc:parent_of
sioc:Forum	A discussion area on which Posts or entries are made. sub-class-of: sioc:Container in-range-of: sioc:has_scope sioc:host_of sioc:moderator_of in-domain-of: sioc:has_host sioc:has_moderator sioc:scope_of
sioc:Item	A content Item that can be posted to or created within a Container. sub-class-of: foaf:Document in-range-of: sioc:container_of sioc:creator_of sioc:has_reply sioc:modifier_of sioc:next_by_date sioc:next_version sioc:previous_by_date sioc:previous_version sioc:reply_of in-domain-of: sioc:about sioc:has_container sioc:has_creator sioc:has_modifier sioc:has_reply sioc:ip_address sioc:next_by_date sioc:next_version sioc:previous_by_date sioc:previous_version sioc:reply_of
sioc:Post	An article or message that can be posted to a Forum. sub-class-of: sioc:Item in-range-of: sioc:related_to sioc:sibling in-domain-of: sioc:attachment sioc:content sioc:note sioc:num_replies sioc:related_to sioc:sibling
sioc:Role	A Role is a function of a User within a scope of a particular Forum, Site, etc. in-range-of: sioc:has_function sioc:scope_of in-domain-of: sioc:function_of sioc:has_scope
sioc:Site	A Site can be the location of an online community or set of communities, with Users and Usergroups creating Items in a set of Containers. It can be thought of as a web-accessible data Space. sub-class-of: sioc:Space in-range-of: sioc:administrator_of sioc:has_host in-domain-of: sioc:has_administrator sioc:host_of
sioc:Space	A Space is a place where data resides, e.g., on a website, desktop, fileshare, etc. in-range-of: sioc:has_space sioc:usergroup_of in-domain-of: sioc:has_usergroup sioc:space_of
sioc:Thread	A container for a series of threaded discussion Posts or Items. sub-class-of: sioc:Container
sioc:UserAccount / sioc:User	A User account in an online community site. sub-class-of: foaf:OnlineAccount in-range-of: sioc:function_of sioc:has_administrator sioc:has_creator sioc:has_member sioc:has_moderator sioc:has_modifier sioc:has_owner sioc:has_subscriber in-domain-of: sioc:account_of sioc:administrator_of sioc:avatar sioc:creator_of sioc:email sioc:email_sha1 sioc:has_function sioc:member_of sioc:moderator_of sioc:modifier_of sioc:owner_of sioc:subscriber_of
sioc:Usergroup	A set of User accounts whose owners have a common purpose or interest. Can be used for access control purposes. in-range-of: sioc:has_usergroup sioc:member_of in-domain-of: sioc:has_member sioc:usergroup_of

TABLE III. SIOC Classes and Properties

class sioc:User is a sub-class of foaf:OnlineAccount and the property foaf:holdsOnlineAccount is able to link a person to all his/her online accounts. SKOS classes and properties such as skos:Concept and skos:isSubjectOf describe the contents of the posts and the information itself within the users online accounts. Therefore, the three ontologies (SIOC, FOAF and SKOS) can be used together in collaboration to produce an integrated framework.

In the authors' opinion, the related classes and properties of the discussed semantic web ontologies would help build a holistic framework that can describe user-generated content in social network sites and connect them appropriately. They propose that the use of FOAF can help define multiple accounts in social network sites belonging to the same user, which would allow for SIOC to articulate user-content on the sites. Then by using SKOS, it would be possible to define the most related ontology to each user-content and tag it appropriately.

However, the authors only explored the current ontology technologies and their possible interaction to build the mentioned framework, but neither implemented such framework nor tested it empirically on social network sites to see whether it achieved the goals of creating more connectivity and having a better user content management system.

They mentioned further work was necessary to convert the theoretical framework into a practical one.

3 CONCLUSION

Based on the resources analyzed we have seen that the semantic web is still growing and evolving and eventually will allow for an interconnected web of social networks. The research we reviewed, did not provide an implementation but did describe how these technologies, methods, and concepts can be applied together to create a more connected and machine friendly web. The reach of semantic web goes far beyond social networks and we only scratched the surface of one area of its application and usefulness.

4 FUTURE WORK

- A common framework RDFs/OWL that can be used to generalize and relate social networks to each other so that users can be identified across networks.
- A means of linking users across social networks and then consolidating their content so that the user and their content as a whole can be queried.
- A means of detecting a user being a member of multiple social networking sites and linking those

Elements	Definition
Contributor	An entity responsible for making contributions to the resource.
Coverage	The spatial or temporal topic of the resource, the spatial applicability of the resource, or the jurisdiction under which the resource is relevant.
Creator	An entity primarily responsible for making the resource.
Date	A point or period of time associated with an event in the lifecycle of the resource.
Description	An account of the resource.
Format	The file format, physical medium, or dimensions of the resource.
Identifier	An unambiguous reference to the resource within a given context.
Language	A language of the resource.
Publisher	An entity responsible for making the resource available.
Relation	A related resource.
Rights	Information about rights held in and over the resource.
Source	A related resource from which the described resource is derived.
Subject	The topic of the resource.
Title	A name given to the resource.
Type	The nature or genre of the resource.

TABLE IV. Dublin Core (DC) Elements which describe properties of SIOC content items.

multiple accounts to one resource by filtering out users that share similar attributes and identifying characteristics.

REFERENCES

- [1] *Social Networks and the Semantic Web*, vol. 5 of *Semantic Web and Beyond*. Boston, MA: Springer US, 2007.
- [2] "FOAF Vocabulary Specification." <http://xmlns.com/foaf/spec/20140114.html>[Accessed 2016-03-26].
- [3] J. Gracia and E. Mena, "Dealing with Semantic Heterogeneity Issues on the Web," *IEEE Internet Computing*, 2011.
- [4] M. Jamalzadeh and N. Behravan, "Using semantic web ontologies for better inter-operability on social network sites," in *Control System, Computing and Engineering (ICCSCE), 2011 IEEE International Conference on*, pp. 103–108, Nov 2011.
- [5] "SKOS Simple Knowledge Organization System Reference." <https://www.w3.org/TR/2009/REC-skos-reference-20090818/>[Accessed 2016-03-26].
- [6] "SIOC Core Ontology Specification." <https://www.w3.org/Submission/sioc-spec/>[Accessed 2016-03-26].
- [7] "DCMI Home: Dublin Core Metadata Initiative (DCMI)." <http://dublincore.org/>[Accessed 2016-03-26].