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Ontology-Based Approach for Temporal Semantic Modeling of Social Networks

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***Abstract*—**Social networks have recently gained a growing interest on the web. Traditional formalisms for representing social networks are static and suffer from the lack of semantics. In this paper, we will show how semantic web technologies can be used to model social data. The SemTemp ontology aligns and extends existing ontologies such as FOAF, SIOC, SKOS and OWL-Time to provide a temporal and semantically rich description of social data. We also present a modeling scenario to illustrate how our ontology can be used to model social networks.

***Keywords*—**Ontology, semantic web, social network, temporal modeling.

I. Introduction

SOCIAL NETWORKS (SN) have received a surge of attention in the recent years. This can be explained by the fact that these social networks allow users to connect to each other and to share and exchange diverse kinds of information; Thiers posts, activities, events and interests among them [1].

The exponential growth of Social Networks makes it more interesting and so hard to analyze and to take use of it, because the large amount of social data is unstructured. That recognizes the need for new models for representing social network.

Traditional formalisms generally use graphs to represent the social structure [2]-[4]; the nodes models social actors while links models relations between them. These formalisms suffer from a range of problems. They luck from semantics and a lot of information about nodes and links are ignored. They are less expressive and represent only simple networks and do not take into account heterogeneity of nodes and links. In a real social network, like Facebook for example, the nodes can represent individuals, organizations, resources, etc., and the links can represent various types of relationship (e.g. friendship, family, colleague, etc.). The individuals have also different roles and different status. Another issue concerns the dynamic aspect. The social structure evolves over time. Individuals can join or leave the network. Relationships can change also; they can be added or removed from the network. The temporal evolution of the social network is very important and can provide enhancements in social network analysis. However, most proposals provide a static description and dynamic of social network is frequently overlooked. Other serious problem relies to interoperability. Indeed, the existing models are not suitable for exchanging data between multiple social applications.

One of the primary goals of Semantic Web is to promote integration and interoperability [5]. Ontology form a vital component in the semantic web by building a formal representation that can provide meaningful description and linkage across data.

We aim in this work to use semantic web technologies to provide a temporal semantic representation of social networks. The main contribution is the development of SemTemp ontology that extends and aligns existing vocabularies [6]-[8], [12]. This contribution is detailed as follows: Section II deals with the related work done in social networks modeling. Section III details the development the SemTemp ontology. Section IV describes the implementation of our ontology. Section V shows some modeling examples that illustrate usage of the ontology. Section VI, concludes the paper.

II. Related Work

The first representation of social networks has been proposed in the early 1930s by Moreno [9] and called "sociogram". It provides a graphical representation of the social structure; the individuals are represented by circles, rectangles and relationships by liens. It represents only relationships of attraction or repulsion. This representation is adopted for restricted groups and becomes unreadable for wide networks.

In the middle of the twentieth century, graph theory [2] has become the conventional representation of social networks. A graph consists of a set of points and lines (oriented or non-oriented, weighted or unweighted, labeled or unlabeled) connecting tow points, called respectively vertices and edges. Several graph based-models are proposed. The Oriented graphs are adopted for representing social networks with symmetric relationships, like "friend" and "family" relationships in Facebook. In contract, nonsymetric relationships, like "Follow" in Twitter are modeled using non oriented graphs. Weighted graphs are often used to model networks where links have different intensity levels. The weights on edges denote the occurrence of interactions (e.g. number of messages, or comments) between people. Labeled graphs are well suited to model social networks with different types of relationships. In Facebook for example, the labels: friend, family, favorite, etc. are used to type relationships. Bipartite graphs are commonly used to model networks using two types of nodes, like content-sharing sites Flickers,

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YouTube, Delicious. Multiplex graphs model complex relationship involving at least three vertices. They are used, in particular, to model social networks integrating tagging systems. Temporal graphs have recently used to represent dynamic networks [10]. They are modeled using contact sequences or interval graph. The contact sequences represent the instant of contact between two entities and they are well suited for modeling social networks including messaging services, forums, microblogs, etc. The interval graphs specify the interval of contact and they are often used to model interactions in form of dialogs, like in chat and visio-conferences. The graph–based models are adopted for a long time and still reused as mathematical representation of social networks. However, it presents notable limitations, including the lack of semantics. Whereas, more of useful information about nodes and links are not considered and only structural properties are represented. Moreover, these models are not suitable for data exchange between social applications.

Semantic web is designed to promote interoperability by providing a web of machine readable data [5]. It is built using ontology which is an explicit specification of a shared conceptualization [11]. Ontologies represent the knowledge of a specific domain in a formal and readable way. Several ontologies are used for representing social data. FOAF[1] (Friend Of a Friend) [6] is the most popular. It is used to describe people and their social connections. FOAF vocabulary defines the user profile by name, e-mail, web/blog address, interests, etc. the “Knows” property is used to connect people. FOAF is often mapped to RELASHIONSHIP[2] ontology which is used to type “Knows” relationship. The SIOC[3] ontology (Semantically-Interlinked Online Communities) [7] describes the interactions and the content produced and exchanged within online communities. “Forum” class represents a space in which discussion is happened, and contains different “Posts”, written “Users”. SIOC defines mappings FOAF vocabulary. SKOS[4] (Simple Knowledge Organization System) [8] ontology can also be associated to SIOC. It is standard vocabulary that enables to organize concepts. These ontological representations provide a semantically rich description of people, their relationships, activities and content in social networks, but in a static way.

III. SemTemp Ontology Development

Our objective in this work is to extend and align the existing vocabularies (i.e. FOAF, SIOC and SKOS) in order to integrate temporal evolution of the social network. We develop the ontology “SemTemp” which provides a semantic temporal description for social networks. In following section, we describe the two principals for SemTemp ontology development:

A. Semantic Social Network Modeling

SemTemp ontology contains mappings between several existing domain ontologies which semantically describe social network. These vocabularies provide a rich and formal description about users and their profiles, activities and their relations to others users and objects. The external ontologies to which the SemTemp ontology refers can be found in Table I.

TABLE I
External Ontologies that SEMTEMP is Linked to

Ontology	Prefix	Name Space
FOAF	Foaf	http://xmlns.com/foaf/0.1/
RELATIONSHIP	Rel	http://purl.org/vocab/relationship/
SIOC	Sioc	http://rdfs.org/sioc/ns#
SKOS	Skos	http://www.w3.org/2004/02/skos/core.html

Different kinds of mapping are used. RDF mapping is based on rdfs:SubClassOf and rdfs:SubPropertyOf. This type of mapping is less expressive. OWL mapping describes more complex mapping. It is based on owl: EquivalentProperty and owl: EquivalentClass.

In FOAF vocabulary “Knows” property states a relationship between two persons. RELATIONSHIP ontology provides a set of properties for a rich typing of interpersonal relationships. rdfs: SubClassOf is used to most of these properties to “foaf:Knows.

SIOC ontology describes social networking sites and online communities. It precisely defines the primitives like users, the content they share and the activities of other users on this content. SIOC defines mappings with FOAF vocabulary. For example, each sioc:User is related to the foaf: Agent.

SKOS offers a way to organize concepts through semantic properties (e.g. narrower, broader and related) and link them to SIOC property “sioc:IsSubjetcOf”.

Table II illustrates some mappings between FOAF, SIOC and SKOS.

TABLE II
Mappings between FOAF, SIOC and SKOS Ontologies

Subject	Predicate	Object
sioc : User	rdsf : SubClassOf	foaf :OnlineAccount
sioc : UserAccount	rdsf : SubClassOf	foaf :OnlineAccount
foaf : Person	foaf : HoldsAccount	sioc : User
sioc : Post	rdsf : SubClassOf	foaf : Document
skos : Concept	skos : IsSubjectOf	sioc : Post
sioc : Post	sioc : Topic	skos : Concept
skos: concept	foaf: InterestTopic	foaf: Person
sioc : User	rdsf : SubClassOf	foaf :OnlineAccount

B. Modeling Temporal Evolution of Social Networks

Social networks are in constant state of evolution. In fact, people’ friendships, affiliations and positions change over time. Moreover, the amount content exchanged grows increasingly. The network temporal evolution is modeled by reusing OWL-Time [5] ontology [12]. The SemTemp ontology aligns existing vocabularies with OWL-time ontology. The temporal properties like « sioc :CreatedAt » of « sioc :user » class is defined as equivalent property of « time :XSDDATE »

[1] FOAF, http://www.foaf-project.org/
[2] RELATIONSHIP, http://vocab.org/relationship/
[3] SIOC, http://sioc-project.org/
[4] SKOS, http://www.w3.org/2004/02/skos/
[5] OWL, http://www.w3.org/TR/owl-time/

of « time :instant » class. Table III shows mapping between SIOC, FOAF and OWL-Time.

TABLE III
MAPPING BETWEEN FOAF AND RELATIONSHIP

Domain	Propriety	Mapping	Range	Propriety
Sioc : User	CreatedAt	owl: EquivalentProperty	time : Instant	time : inXSDDateTime
	ModifiedAt	owl: EquivalentProperty	time : Instant	time : inXSDDateTime
Sioc : Post	ClosedAt	owl: EquivalentProperty	time : Instant	time : inXSDDateTime
	CreatedAt	owl: EquivalentProperty	time : Instant	time : inXSDDateTime
	ModifiedAt	owl: EquivalentProperty	time : Instant	time : inXSDDateTime
Sioc : Forum	CreatedAt	owl: EquivalentProperty	time : Instant	time : inXSDDateTime
	ModifiedAt	owl: EquivalentProperty	time : Instant	time : inXSDDateTime
foaf : Person	Birthday	owl: EquivalentProperty	time : Instant	time : inXSDDateTime
foaf : Group	Birthday	owl: EquivalentProperty	time : Instant	time : inXSDDateTime

SemTemp extends semantic vocabularies by defining new binary temporal properties (see Table IV).

TABLE IV
BENARY TEMPORAL PROPERTIES OF SEMTEMP ONTOLOGY

Domain(s)	Property	Range(s)
foaf : Organization	SemTemp: BuiltAt	time: Instant
foaf : Group	SemTemp: FormedAt	time: Instant
foaf : Group	SemTemp: ClosedAt	time: Instant
foaf : Project	SemTemp : HasDuration	time: ProperInterval
sioc: OnlineAccount	SemTemp: CreatedAt	time: Instant

SemTemp extends semantic vocabularies by defining new complex relationships in order to integrate temporal information on the available properties. Instead of using simple relations relating one pair of subjects, SemTemp ontology models n-ary relations that connect several subjects with a signal relation. Therefore, this can models temporal properties describing the beginning and the end of a relation. For example, the binary property « foaf :Knows » relating two people, can be extended to represent properties describing the date that the relationship began and the date when it ended. SemTemp defines the ternary relationship « semtemp : Knows_At » relating two persons « foaf :Person » with « time : interval ». Table V lists the n-ary relations of Semtemp ontology.

TABLE V
N-ARY RELATIONS OF SEMTEMP ONTOLOGY

Domaine(s)	Classe
foaf : Person, foaf : Group, time: Instant	SemTemp : JoinGroupAt
foaf : Person, foaf : Person, time: Instant	SemTemp : KnowPersonAt
foaf: Person, foaf: Document, time: Instant	SemTemp : IntersetedDocumentAt
sioc: UserAccount, sioc: UserAccount, time: Instant	SemTemp : StartingFollwingAt
foaf : Person, sioc: Role, time: Instant	SemTemp : HasFunctionAt

In what follow, we detail the n-ary relations of SemTemp ontology.

1) SemTemp : JoinGroupAt

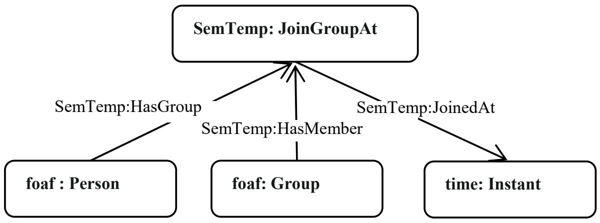

Fig. 1 “JoinGroupAt” n-ary relation

2) SemTemp : KnowPersonAt

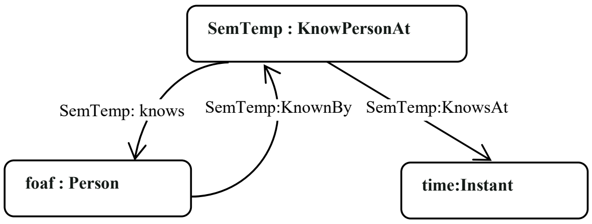

Fig. 2 “KnowPersonAt” n-ary relation

3) SemTemp : IntherstedDocumentAt

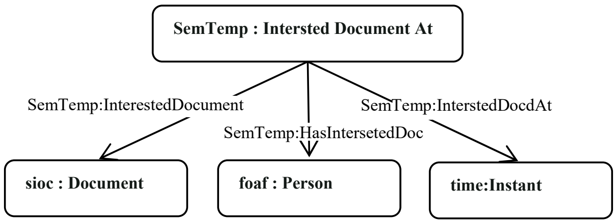

Fig. 3 “IntherstedDocumentAt” n-ary relation

4) SemTemp : StartingFollwingAt

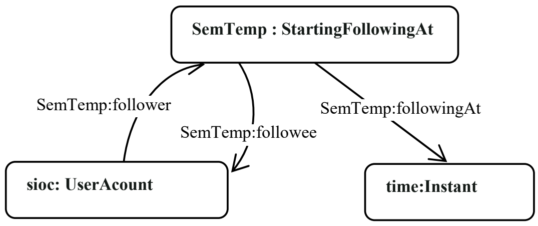

Fig. 4 “StartingFollwingAt” n-ary relation

5) SemTemp : HasFunctionAt

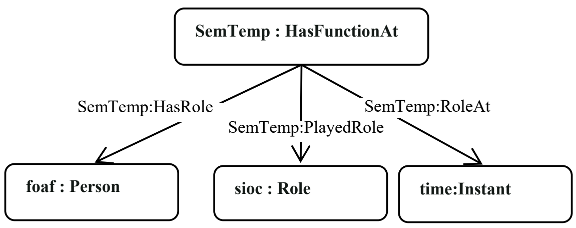

Fig. 5 “HasFunctionAt” n-ary relation

IV. Ontology Implementation

The SemTemp ontology is developed using Protégé which is an open source ontology editor distributed by the University of Stanford Medical Informatics. Protégé is a highly extensible editor, able to handle a wide variety of formats (RDF, OWL, etc.). Our ontology is represented in OWL Web Ontology Language, an XML-based formal language, which provides a formal way to describe domain concepts. A view of the created ontology is shown in Fig. 6.

V. Modelling Examples

In this section, we will demonstrate how our ontology can be used to provide a semantically rich and temporal description of social data.

The following examples can be easily expressed using SemTemp description (see Fig. 7). However, this is not possible with the existing vocabularies.

1) Paul became friend of John in 02/01/2009.
2) John joined "scientific papers" group in 21/05/2013.
3) John starting following of Paul in 03/01/2009.
4) Susun is interested by the document "ubuntu" in 28/01/2015.
5) John has posted the response "Hello …" to the Paul's post "Question …".

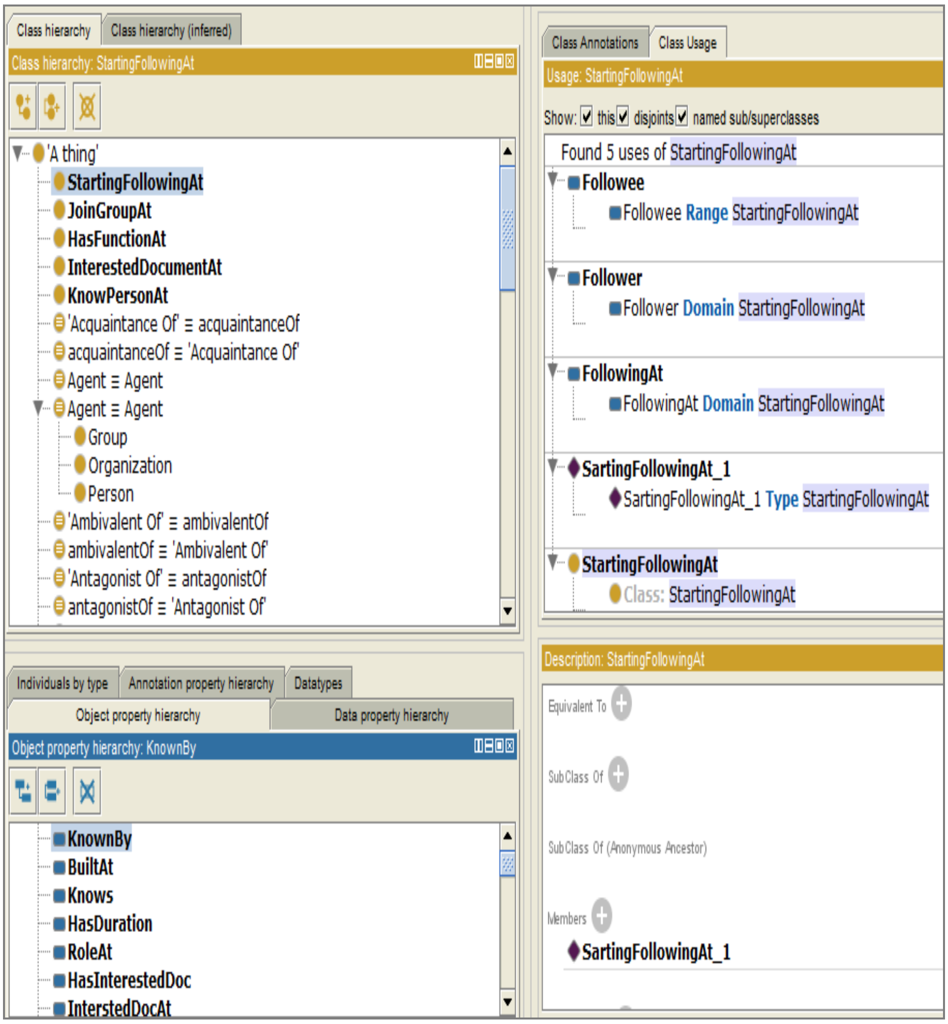

Fig. 6 SemTemp via Protégé editor

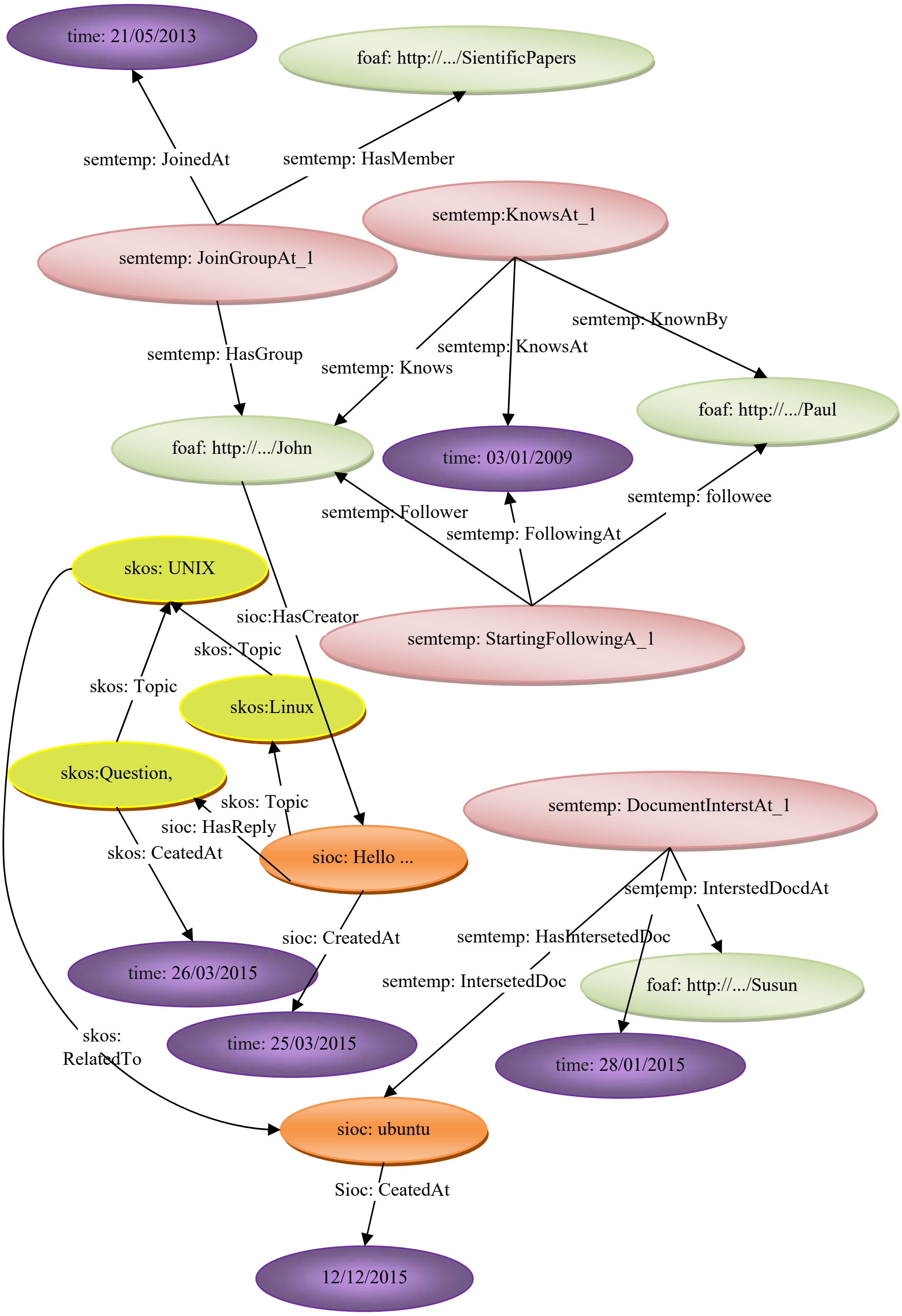

Fig. 7 Example described by SemTemp Ontology

The following OWL encodings shows John's friendship which was established in 02/01/2009.

```
<Ontology xmlns="http://www.w3.org/2002/07/owl#"
 xml:base="http://www.semanticweb.org/souad/ontologies/2015/3/SemTemp"
 …
 <Import>http://xmlns.com/foaf/0.1/</Import>
 <Import>http://purl.org/vocab/relationship/</Import>
 <Import>http://www.w3.org/2004/02/skos/core</Import>
 <Import>http://rdfs.org/sioc/ns#</Import>
 <Import>http://www.w3.org/2006/time</Import>
<Declaration> <Class IRI="#KnowPersonAt"/> </Declaration>
 <Declaration><ObjectProperty IRI="#KnownBy"/> </Declaration>
 <Declaration><ObjectProperty IRI="#Knows"/> </Declaration>
 <Declaration> <ObjectProperty IRI="#KnowsAt"/> </Declaration>
 <Declaration> <NamedIndividual IRI="#Paul"/> </Declaration>
 <Declaration> <NamedIndividual IRI="#knowPersonAt_1"/> </Declaration>
 <Declaration> <NamedIndividual IRI="#time"/> </Declaration>
 <ClassAssertion> <Class IRI="http://xmlns.com/foaf/0.1/Person"/>
 <NamedIndividual IRI="#John"/> </ClassAssertion>
 <ClassAssertion> <Class IRI="http://xmlns.com/foaf/0.1/Person"/>
 <NamedIndividual IRI="#Paul"/> </ClassAssertion>
 <ClassAssertion> <Class IRI="#KnowPersonAt"/>
 <NamedIndividual IRI="#knowPersonAt_1"/> </ClassAssertion>
 <ObjectPropertyAssertion><ObjectProperty IRI="#Knows"/> <NamedIndividual IRI="#John"/>
 <NamedIndividual IRI="#knowPersonAt_1"/></ObjectPropertyAssertion>
 <ClassAssertion> <Class IRI="http://www.w3.org/2006/time#Instant"/>
 <NamedIndividual IRI="#time"/> </ClassAssertion>
 <ObjectPropertyAssertion> <ObjectProperty IRI="#KnownBy"/> <NamedIndividual IRI="#Paul"/>
 <NamedIndividual IRI="#knowPersonAt_1"/> </ObjectPropertyAssertion>
 <DataPropertyAssertion><DataProperty IRI="http://www.w3.org/2006/time#xsdDateTime"/>
 <NamedIndividual IRI="#time"/> <Literal datatypeIRI="&xsd;dateTime">11/03/2015</Literal>
 </DataPropertyAssertion>
 <ObjectPropertyDomain> <ObjectProperty IRI="#KnownBy"/>
 <Class IRI="http://www.w3.org/2000/10/swap/pim/contact#Person"/>  </ObjectPropertyDomain>
 <ObjectPropertyDomain>  <ObjectProperty IRI="#Knows"/>
 <Class IRI="#KnowPersonAt"/>  </ObjectPropertyDomain>
 <ObjectPropertyDomain> <ObjectProperty IRI="#KnowsAt"/>
 <Class IRI="#KnowPersonAt"/> </ObjectPropertyDomain>
 <ObjectPropertyRange> <ObjectProperty IRI="#KnownBy"/>
 <Class IRI="#KnowPersonAt"/>  </ObjectPropertyRange>
<ObjectPropertyRange>
 <ObjectProperty IRI="#Knows"/>  <Class IRI="http://xmlns.com/foaf/0.1/Person"/>
</ObjectPropertyRange>
 <ObjectPropertyRange>  <ObjectProperty IRI="#KnowsAt"/>
 <Class IRI="http://www.w3.org/2006/time#Instant"/> </ObjectPropertyRange>
```

Fig. 8 OWL encodings

VI. Conclusion

In this paper, we have described our work for representing semantics and temporal evolution of social data based on ontological approach. We have presented SemTemp ontologies that extend and align existing ontologies: FOAF, SIOC and SKOS for semantic description of people and their content in the web with the temporal ontology OWL-Time. SemTemp provides temporal and semantically rich description of social networks, in a machine readable way. Modeling examples have also been shown to illustrate the use of our ontology.

Future work will include the integration of more ontologies in order to better describe social organization. SCOT [13] and MOAT [14] ontologies can be integrated to SemTemp ontology to provide more details about the generated content in social networks. The content created in SemTemp can be consumed by semantic web application. In the next step, we will develop social networks analysis and community detection tools that takes advantage from the temporal semantic description in SemTemp.

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