Ontology-Based Approach for Temporal Semantic Modeling of Social Networks
Souâad Boudebza, Omar Nouali, Faiçal Azouaou

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; Thrones 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 lack 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, nonsymmetric 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,
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>
<thead>
<tr>
<th>Ontology</th>
<th>Prefix</th>
<th>Name Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOAF</td>
<td>Foaf</td>
<td><a href="http://xmlns.com/foaf/0.1/">http://xmlns.com/foaf/0.1/</a></td>
</tr>
<tr>
<td>RELATIONSHIP</td>
<td>Rel</td>
<td><a href="http://purl.org/vocab/relationship/">http://purl.org/vocab/relationship/</a></td>
</tr>
<tr>
<td>SIOC</td>
<td>Sioc</td>
<td><a href="http://rdfs.org/sioc/ns#">http://rdfs.org/sioc/ns#</a></td>
</tr>
<tr>
<td>SKOS</td>
<td>Skos</td>
<td><a href="http://www.w3.org/2004/02/skos/core.html">http://www.w3.org/2004/02/skos/core.html</a></td>
</tr>
</tbody>
</table>

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.

B. Modeling Temporal Evolution of Social Networks

Social networks are in constant state of evolution. In fact, people’s 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>
<thead>
<tr>
<th>Domain</th>
<th>Propriety</th>
<th>Mapping</th>
<th>Range</th>
<th>Propriety</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIOC: User</td>
<td>CreatedAt</td>
<td>owl: EquivalentProperty</td>
<td>time:</td>
<td>instant</td>
</tr>
<tr>
<td></td>
<td>ModifiedAt</td>
<td>owl: time:</td>
<td></td>
<td>inXSDDateTime</td>
</tr>
<tr>
<td>SIOC: Post</td>
<td>CreatedAt</td>
<td>owl: EquivalentProperty</td>
<td>time:</td>
<td>instant</td>
</tr>
<tr>
<td></td>
<td>ModifiedAt</td>
<td>owl: time:</td>
<td></td>
<td>inXSDDateTime</td>
</tr>
<tr>
<td>SIOC: Forum</td>
<td>CreatedAt</td>
<td>owl: EquivalentProperty</td>
<td>time:</td>
<td>instant</td>
</tr>
<tr>
<td></td>
<td>ModifiedAt</td>
<td>owl: time:</td>
<td></td>
<td>inXSDDateTime</td>
</tr>
<tr>
<td>FOAF: Person</td>
<td>Birthday</td>
<td>owl: time:</td>
<td></td>
<td>instant</td>
</tr>
<tr>
<td>FOAF: Group</td>
<td>Birthday</td>
<td>owl: time:</td>
<td></td>
<td>instant</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Domain(s)</th>
<th>Property</th>
<th>Range(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOAF: Organization</td>
<td>SemTemp: BuiltAt</td>
<td>time: Instant</td>
</tr>
<tr>
<td>FOAF: Group</td>
<td>SemTemp: FormedAt</td>
<td>time: Instant</td>
</tr>
<tr>
<td>FOAF: Group</td>
<td>SemTemp: ClosedAt</td>
<td>time: Instant</td>
</tr>
<tr>
<td>FOAF: Project</td>
<td>SemTemp: HasDuration</td>
<td>ProperInterval</td>
</tr>
<tr>
<td>SIOC: OnlineAccount</td>
<td>SemTemp: CreatedAt</td>
<td>time: Instant</td>
</tr>
</tbody>
</table>

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 : InterstedDocumentAt

Fig. 3 “InterstedDocumentAt” n-ary relation

4) SemTemp : StartingFollowingAt

Fig. 4 “StartingFollowingAt” 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](image-url)
Fig. 7 Example described by SemTemp Ontology
The following OWL encodings shows John’s friendship which was established on 02/01/2009.

```xml

<Declaration> <Class IRI="#KnowPersonAt"/> </Declaration>
<Declaration> <ObjectProperty IRI="#KnownBy"/> </Declaration>
<Declaration> <ObjectProperty IRI="#Knows"/> </Declaration>
<Declaration> <ObjectProperty IRI="#KnowsAt"/> </Declaration>
<Declaration> <NamedIndividual IRI="#John"/> </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"/> </ObjectPropertyDomain>
<ObjectPropertyDomain> <ObjectProperty IRI="#KnowPersonAt"/> </ObjectPropertyDomain>
<ObjectPropertyDomain> <ObjectProperty IRI="#KnowsAt"/> </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="#KnowPersonAt"/> </ObjectPropertyRange>
<ObjectPropertyRange> <ObjectProperty IRI="#KnowsAt"/> </ObjectPropertyRange>
<ObjectPropertyRange> <ObjectProperty IRI="#Knows"/> <Class IRI="http://xmlns.com/foaf/0.1/Person"/> </ObjectPropertyRange>
<ObjectPropertyRange> <ObjectProperty IRI="#KnowPersonAt"/> </ObjectPropertyRange>
<ObjectPropertyRange> <ObjectProperty IRI="#KnowsAt"/> </ObjectPropertyRange>
<ObjectPropertyRange> <ObjectProperty IRI="#Knows"/> <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.

REFERENCES