Towards a Semantic Approach for the Design of Social Network Users' Geographical Trajectories

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Abstract: The volume of data keeps growing rapidly, especially with the arrival and the frequent access to social networks. The spread of these networks provides users the opportunity to share their social, geographical and temporal information through geo-localized tweets and check-ins. The challenge is to exploit these data leads to a decision in favour of different situations encountered by these users. Thus, if we successfully analyze their trends according to the models of users' movements, we can then draw conclusions about the evolution of their instantaneous behavior and accomplished activities. But, the problem is that the use of such data decrees the provision of a representative formalism that combines spatial data and user information. In this paper, we propose an approach for a semantic modeling of social network users' trajectories. To do so, ontology seems to be a promising solution that allows us to annotate raw trajectories with semantic information to give birth to semantic trajectories. Such semantic trajectories are then analyzed in order to detect user behavior in a dynamic way.

1 INTRODUCTION

These years were marked by the advent of web 2.0 and web 3.0. Such latest technologies have allowed the influx of social networking. Hence, Facebook, Twitter, LinkedIn, Google+, and many others are considered as new darlings of Web 2.0 on the web. Social networks are booming because they attract more and more users and researchers. Today, they allow users to share their personal information, their desires and their photos, to communicate and record movements tracks through GPS technology integrated in mobile phones (smartphones, PDAs, IPhone, etc.). This vigorous prosperity gave birth to Twitter Places in June 2010 and Facebook Places end of August 2010, where each includes its own geolocation application. Moreover, this new application collects the trajectory data generated by users which are defined as traces of people in motion. Therefore, data that convey these networks are huge amounts concealing important conclusions. In fact, this research area has persuaded a lot of researchers to understand the user's behavior by referring to their movements.

Various problems are derived from this context. (i) The first problem is to know how to benefit from the great mass of geographic information. This information is increasingly accessible and available through the movement of persons registered at each moment. Our interest is to get benefits not only from this information but also to exploit other existing information on these networks such as the metadata i.e., *name and type of the place, time, comments on a subject, photos, mood and friendships*. (ii) The second problem is the need to identify, analyze and understand the behavior of Internet users through social networks by exploiting their trajectories. Treatment of semantics related to trajectories will be essential in order to achieve semantic behaviors. Therefore, taking trajectories in their raw states is an unavoidable problem since the exploration and analysis of behavior will always be limited and insufficient. More concretely, to ensure proper handling of information, we must consider a semantic enrichment which extends raw data to other contextual information representing the meanings.

The main objective of this paper is to propose a semantic approach for modeling social network users 'trajectories in order to explore later the behavior of Internet users. Our approach focuses on solving problems of modeling data collected from social networks. Such data are based mainly on related

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locations of the user, where we will discuss the geographical coordinates of locations and also exploit the proportional metadata. That's why, we should make a semantic enrichment of these trajectories to move from raw trajectories to semantic trajectories by using domain ontology models that represent the raw data and their annotations.

The remainder of this paper is organized as follows: section 2 gives an overview of related work. Section 3 describes the proposed approach. Section 4 proposes semantic trajectory ontology. Section 5 concludes by stating the main research ideas.

2 RELATED WORK

The following sub-sections report few works in the literature describing social network trajectory data, review works on trajectory analysis based on ontological approaches and introduce the most popular geospatial ontologies.

2.1 Social Media Trajectory Analysis

The geographical aspect integrated to social networks has attracted many researchers. Between (Foursquare, Twitter, Facebook, etc.), numerous works has been established, where these researchers have proposed their approaches for achieving a better understanding of human mobility. Some of them focus only on behavior analysis, others propose a semantic enrichment from different sources and others predict the future locations of users in time and in space.

On the Foursquare network, a lot of work is developed. Some of them include the analysis of behaviors and others focus on the prediction of future locations. The work of (Kling and Pozdnoukhov, 2012) studied the movement patterns and location based Foursquare Twitter messages to extract the semantics behind users' activities. (Long and al, 2012) explored the check-ins of Foursquare users to determine their trajectories in order to understand their preferences sites. Then, the contribution is a recommendation of appropriate locations for each intended user. (Preotiuc-Pietro and Cohn, 2013) offered on the one hand the discovery models of user behavior according to their movements based on the clustering techniques. On the other hand, it has planned their future movements by referring to successful models. It is a research that is integrated in order to develop interesting applications such as recommendation systems. In fact, the authors undertake to focus on the type of places and their evolution over time. (Preotiuc-Pietro and Cohn, 2013) have not only sought to go beyond the geo-coordinates of users over time but also to use metadata as the name of the location, type, comments photos. Another study proposed by Krueger and al. (Krueger and al, 2014) used the social network Foursquare to enrich mobility data extracted from another source. For this, they have proposed an approach to semantically enrich the geospatial data retrieved from the database e-mobility with the POIs information provided by the Foursquare service. This work ensures to guarantee then the behavior analysis task via the establishment of an interactive visualization tool.

As to Twitter social networking, similar works has been done to achieve the same goal. (Fujisaka and al, 2010) analyzed the users' movements based on Twitter geolocation. They applied a cluster analysis on frequent POIs. (Cheng and al, 2011) studied the check-ins to analyze aspects of human mobility: spatial, temporal, social and textual aspects associated with his fingerprints. (Ferrari and al, 2011) have managed to extract urban models from the location-based social networks (LBSN) in reference to publications Twitter with reference to their movements. (Gong and al, 2011) introduced locations predication system in order to predict the next location of the user. For this, they used Markov models. (Ye and al, 2013) have used the information to model the movement of the user pattern. They proposed a framework that uses a mixed hidden Markov model to predict the category of user activity at the next step and then to predict the most likely location in view of the distribution of the estimated category.

The Facebook social network creates also another search field, where (Backstrom Sun, and Marlow, 2010) have managed to predict the location of such user by referring to these friends. In fact, research conducted from this network remains quite limited because of the high security related to user's profiles and both the database will be also quite narrow if we request to have personal information.

Most of the cited works took trajectories in their basic states without using a semantic enrichment unless the examples of (Krueger and al, 2014), (Preotiuc-Pietro and Cohn, 2013) and (Kling and Pozdnoukhov, 2012) have tried to add some additional information to the places while neglecting the mobile entity that is the user. That's why understanding users' behavior will always remain average and lack of semantics. Moreover the techniques used to solve this problem of understanding human mobility turns around the techniques of data mining and the markov models.

2.2 Trajectory Analysis based on Ontological Approaches

Ontologies are used in the context of modeling trajectories due to their large potential to modelize and manipulate knowledge and provide a better understanding for a subject. Furthermore, ontologies are characterized by semantic interoperability between individuals, systems or individuals and systems (Hepp, 2008).

The trajectory modeling problem has been addressed by various researches. Therefore, we present a work proposed by Spaccapietra (Spaccapietra and al, 2008), which defined the notion of semantic trajectory that are used to decompose the raw data into a series of decision points i.e., *Stop* and *Move*. This division makes the modelization more thin and flexible by providing the ability to add other information coming from different areas.

Thanks to this notion of semantic trajectory, Baglioni (Baglioni and al, 2008) proposes to increase the information content of the trajectory through a semantic enrichment process. In fact, this process enrichs raw trajectory by adding contextual information related to the geographic area or information relevant to the activity of user. Modeling these trajectories is feasible through the Ontology Web Language (OWL) formalism. Thereafter, the obtained ontology covers different components of a trajectory. Concerning the approach proposed by authors in (Baglioni and al, 2008), the conceptualization of a trajectory is represented by a shutdown sequence connected to a movement. This connection is made via four relationships: fromStop, toStop, inMove, outMove. In addition, each Stop is in a specific temporal dimension as the following equation: StopHasTime.

In his doctoral thesis (Yan, 2011), Yan offers a complete architecture for the creation, management and analysis of trajectories. The architecture is a modular infrastructure that consists of three main ontologies: ontology of geometric trajectories, geographic ontology and domain ontology application.

The geometric ontology of trajectory is itself made up of several specialized sub-ontologies in the description of spatial or temporal concepts.

The geographic ontology contains different geographical concepts. These concepts can refer to natural and artificial elements. The ontology of domain application is specific to the domain in which integrates the application.

Among the existing work in this context, Perry (Perry, 2008) chooses to make an analytical application within the military domain. So he proposed an ontological approach that reflects theme, space and time. He is also interested in determining a set of operators specifically relating to application requirements. In fact, these operators support the notion of context and are able to calculate the spatial and temporal relationships. However, data captured in this work does not undergo a semantic annotation process**.**

In the same spirit, we identify the work of Malki and al. (Malki and al, 2012) proposed an ontological approach for the modeling and the analysis of marine mammals' trajectories. This trajectory ontology generated from other ontologies. This approach considers three separate ontology models: a model of domain general trajectory, knowledge domain or semantic model, and time domain model. Other work is involved in the same axis is that of (Vandecasteele, 2013). In fact, this work took its starting point from the research done by (Spaccapietra and al, 2008) speaking about the semantic trajectory and the research done by (Yan, 2011) proposing to regroup information following a consisting set of three ontologies. Vandecasteele (Vandecasteele, 2013) made an analysis of abnormal behavior of ships to arrive to control such a maritime surveillance system. (Hu and al, 2013) proposed a geo-ontology design pattern for semantic trajectories. The formalization of this pattern using OWL and they tried to apply the pattern to two different scenarios, personal travel and wildlife monitoring.

Recently (Manaa and Akaichi, 2016) proposed a generic ontology-based for Semantic Trajectory Data Warehouses using the best of both Data Warehousing and Data Modeling Semantic worlds.

The choice of using ontological approaches is not arbitrary. Indeed, the authors sought the best way to model and to manipulate the trajectories of an expressive and comprehensive manner to ensure thereafter the analysis task.

As our work focuses on trajectory modeling, we are then incited to seek how we can resolve this issue knowing that ontologies are used both to describe geographic concepts and to describe spatial concepts.

2.3 Geospatial Ontologies

The ontological modeling studies of the spatial dimension are quite numerous noting the works of

(INSEE[1], COST UCE[2], GIEA[3], Ordinance Survey[4], etc.) that are dedicated to the use, the representation formalism and philosophical rigor employed. However, works that have full support the description of geographic features are fairly limited. For this reason, we focus only to present (FAO[5], SUMO[9] and BFO[6]), which are defined as high-level ontologies.

FAO[2] described the ontology proposed by the Food and Agriculture Organization of the United States. This latter was are developed to facilitate the exchange and share of data in a standardized way between information systems relating to countries and/or regions. This ontology manages terms into multiple languages.

Besides, it has standardized coding systems (OUN, ISO[7], AGROVOC[8], etc.). FAO[2] expresses the relationship between territories and follows the historic changes. It was benefited from the GeoNames[9] ontology through the addition of different concepts.

Suggested Upper Merged Ontology (SUMO[10]) (Niles and Peace, 2001) is an upper ontology carried by the IEEE Standard Upper Ontology group (SUO). The purpose assigned to SUMO[9] is to establish a standard able to create a semantic interoperability between information systems. Moreover, SUMO[9] has been developed to describe the geographical area. It includes hundreds of concepts and relationships. It is used to design the basic structures of the real world. Indeed, the description of the real world follows two trends: type of objects SNAP and type of objects SPAN.

Moreover, the representation and the manipulation of geographic features require the presence of other standard then OWL because unfortunately it lacks the syntax to describe any spatial type i.e., point, line and polygon. To fill this gap, we call the GeoRSS[11] that is defined as a W3C Recommendation consortium to describe properties of geospatial web resources. Besides, GeoRSS[4] rests in its most advanced version of a standard called Geography Markup Language (GML).

GeoRSS[11] has the advantage of adding the geographical dimension to the Really Simple Syndication (RSS) flux, and it was adopted by W3C as a vocabulary reference for the description of geospatial properties of web resources. In fact, GeoRSS[11] is based on the GML standard to be more generic.

The advantage of using GeoRSS[4] in the ontological context is to provide a simplified spatial representation.

GML is determined by the Open Geospatial Consortium (OGC[12]) and respectively used as a Standard ISO[2] (ISO19136). It has been defined as a standardized language based on XML grammar. GML provides encoding, storage and exchange of the geometry and the attributes of geographic features (Cox et al, 2004). Moreover, the GML format ensures to describe entities, geometry, coordinate systems, units of measure and symbologies. Each element will be described in a GML schema that specifies standard notation and naming.

3 SEMANTIC ANNOTATION OF TRAJECTORIES OF SOCIAL NETWORK USERS

A mobile object moves in space and constructs a trajectory that will itself be formed of a series of spatio-temporal events i.e., *Move and Stop*. Moreover, this spatio-temporal measure seems insufficient if it is alone retained to carry out the analysis of an object in movement. Adding additional information may clarify this movement. In fact, this additional information will contribute to describe the context in which a moving object evolves, so the added value will be a better understanding and interpretation of movements.

To certify this understanding, we will rely on the notion of semantic trajectory which was developed during research works in (Spaccapietra and al, 2008) and (Baglioni and al, 2008) in order to increase the rate of information relating to the mobile object via semantic enrichment process.

This semantic enrichment layer will be from three perspectives: geographic view, temporal view and application domain. The result led eventually to obtain semantic trajectories, easy to be handled and processed by the user by adopting an expressive and understandable language. The literature provides in this context the field of ontologies that are used to

[1] http://www.insee.fr/fr/nom_def_met_/xml_rdf.html
[2] www.towntology.net
[3] www.projetgiea.fr
[4] http://www.odnancesurvey.co.uk/oswebsite/ontology/
[5] http://aims.fao.org/geopolitical.owl
[6] Basic Formal Ontology : http://www.iformis.org/bfo
[7] International Organisation for Formalisation - htttp://www.iso.org/iso/home.html
[8] http://www.fao.org/aims/
[9] http://www.geonames.org/ontology/documentation.html
[10] http://www.ontologyportal.org/
[11] http://www.w3.org/2005/Incubator/geo/XGR-geo-20071023/W3C_XGR_Geo_files/geo_2007.owl
[12] Open Geospatial Consortium – http://www.opengeospatial.org/

meet our needs. Therefore, we use the OWL formalism to represent these trajectories.

Social networks allow to record the history and the tracks of daily users. Therefore, a set of metadata is accumulated through tags, should be useful for the extraction of the user information related to their movements.

The following figure (Figure 1) shows a more concrete example to facilitate modeling trajectory marked by a well-defined user on a well determined geo-social network. The user is interested to mark its current movements and social activities by identifying his friends and mentioning his mood at every time. Therefore, we can use its tagging data to annotate and generate semantic trajectories. The trajectory below is divided into spatio-temporal events (*Moves* and *Stops*) and enriched by the contextual data presented on publications. *Stops* are defined with the tags of (*Home*, *University*, *Restaurant*) and *Moves* are defined with the tags of (*Train*, *Path way*, *Road*).

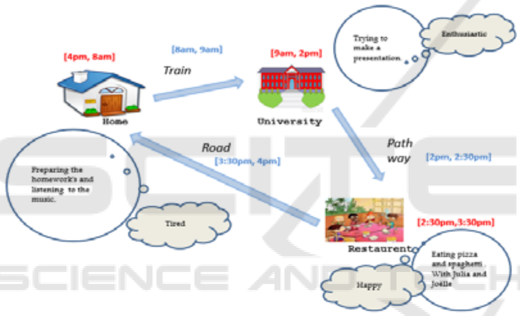

Figure 1: Example of semantic annotation of a trajectory.

4 THE MODELING OF SEMANTIC CONTEXT

Figure 1 presents a semantic trajectory obtained via the semantic annotation, using the marking data and the information on profile. Different trajectories should be modeled via ontologies in order to achieve at an early stage the discovering of semantic behaviors.

To begin our work, we will rely on the ontological model proposed by Yan (Yan, 2009) (Yan, 2011) consisting of three ontologies.

- Ontology of trajectory contains different spatio-temporal concepts necessary for the geometric description of trajectory.
- Geographic ontology contains the specific concepts to the description of a territory. This ontology will be connected to the ontology of trajectories and also to the domain ontology.
- Domain ontology represents the domain to be studied and the concepts and the needed relationships.

Our contribution resides in the creation of a domain ontology related to our subject while we rely on an existing ontology of trajectory and an existing geographic ontology. This highlights the interest of the characteristic of reusability of ontologies.

The model presented in Figure 2 is formed of a:

- ✓ Geometric trajectory ontology forms itself from different ontologies. This ontology provides the basic concepts to describe the semantics of trajectory. It consists of three ontologies:
  - Spatio-temporal ontology represented through the GeoRSS Simple[11] ontology to identify space objects.
  - OWL Time [13]ontology to define the temporal entities.
  - Ontology of trajectory that is formed around the necessary concepts to the description of a trajectory. We will make use of the model defined by (Spaccapietra and al, 2008) to define this ontology.
- ✓ Geographic ontology specifies the geographical concepts related to understanding a trajectory consists of two ontologies FAO[5] and GeoNames[9].
- ✓ Domain ontology will be detailed with SNDO.

4.1 Social Network Domain Ontology (SNDO)

We opt for the classification of ontology models identified by Guarino (Guarino, 1998) which defined, among other things, the domain ontology. In addition, our work is based on the life cycle model of an ontology proposed by Lopez (Lopez, 1999), which is summed up in three main activities (management, construction and support). We emphasize the major classes forming our ontology. Furthermore, in this context, we specifically interested in the construction activity respectively, of four stages (specification, conceptualization, formalization and

[13] http://www.w3.org/2006/

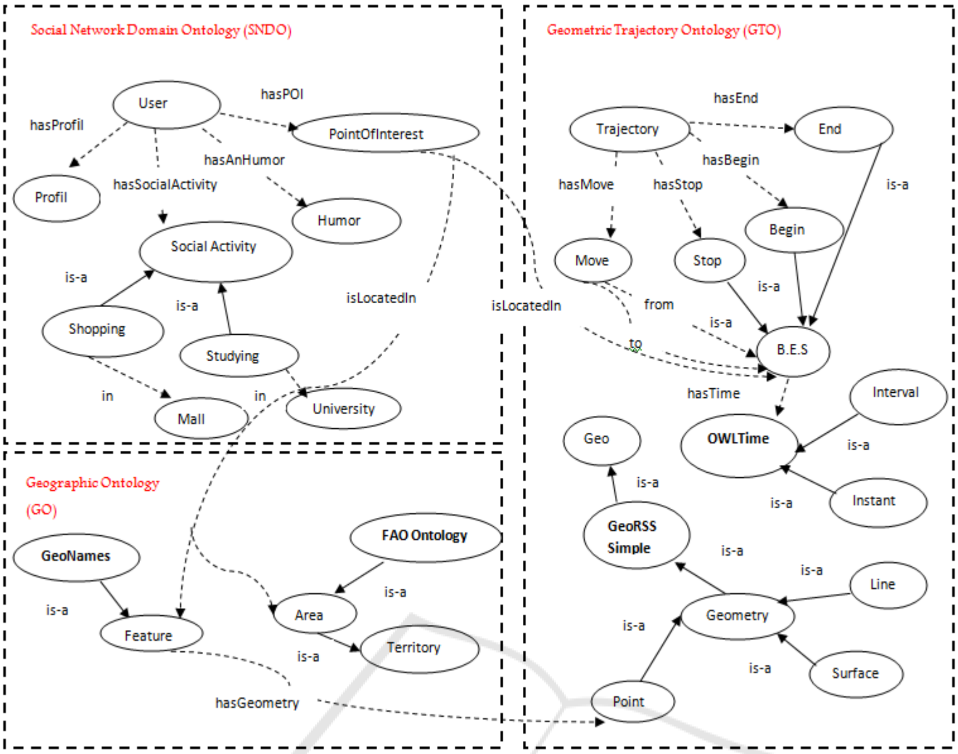

Figure 2: Ontological model for semantic trajectories of social network users.

implementation), we will rely on the methodology proposed by Gandon (Gandon, 2002) to draw up the tables presenting the concepts, attributes and relations between concepts.

User profile: This class focuses on presenting various personal information from the user profile. This information is defined by social networks such as Facebook and Twitter. It is divided into five principal sub-classes (Figure 3).

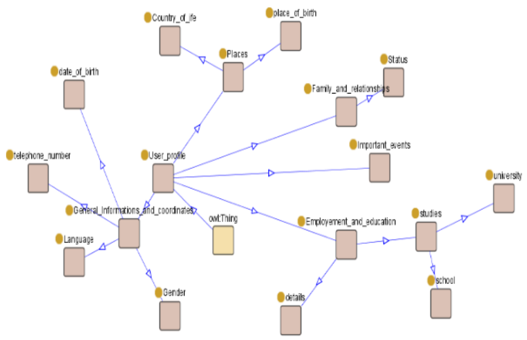

Figure 3: An excerpt of the design of user profile class.

Social activity: Today social networks are able to share social activity marked by users. We can then define these activities following places mentioned on such publication. In fact, we consider them such as semantic social activities (Figure 4).

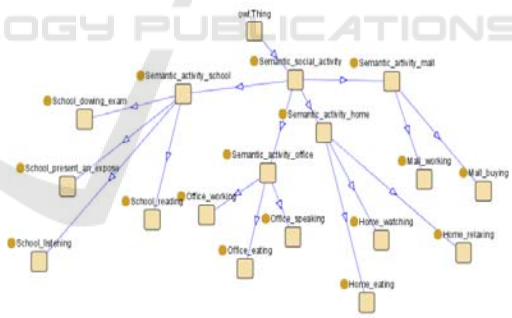

Figure 4: An excerpt of the design of semantic activity class.

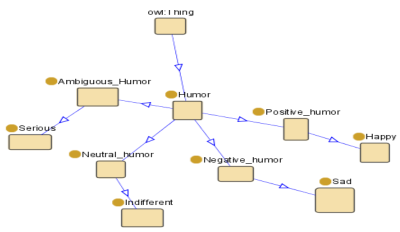

Figure 5: An excerpt of the design of humor class.

Humor: Humors are here, the expression of user's feelings, identified during a marking or a publication. It helps us later to analyze the behavior of different users (Figure 5).

4.2 Conceptualization

Once we defined major classes of our domain ontology, it's necessary at this stage to extract concepts and relations and to mention the logical constraints and inferential knowledge.

- The construction of ontology schema

Ontology is built around multiple concepts connected by hierarchical relationships, type of specification, generalization and semantic relations.

The table of concepts is represented in four columns : the name of the concept (term), the ID is the label of concept (ConceptID), the ID of parent concept which the concept is related (ParentID) and the definition of concept in natural language, as the following table shows (Table 1).

Ontology concepts are formalized through OWL and RDF languages. The following example (Figure 6) translates the concepts (user profile, General information and coordinates).

```
<owl:Class rdf:ID="User_profil">
<rdfs:subClassOf>
<owl:Class rdf:ID="General_Informations_and_ coordinates"/>
</rdfs:subClassOf>
</owl:Class>
```

Figure 6: Concepts (User profile, General information and coordinates).

- The creation of relations

There are two types of relations: attributes and associative relationships. Indeed, attributes are the relation that links a concept to a data type i.e., integer, string, and date. These attributes have a role to add knowledge to the concepts themselves without considering the relationships between these concepts. This knowledge is determined by the extraction of information from Twitter social network users.

Table 1: An excerpt of ontology concepts.

Term	ConceptID	ParentID	Definition
General information and coordinates	General_Information_and_ coordinates	User Profile	Exposes the user information
Humor	Humor	Thing	The mood proven and mentioned in publications
Date of birth	Date_of_birth	General_information_and_coordi nates	Describes the user 'date of birth

Table 2: Attributes.

Relation	ID attribute	Associated concept	Attribute type	Definition
Date of birth	Has_a_date_of_birth	User_profile	Date Time	The date of birth of each user
Mail	Has_a_mail	User_profile	String	Each user has their own mail
Etudié à	Has_studied_in	User_profile	String	School name where the user continues his studies.

Table 3: Relations.

Relation	ID relation	Original concept	Target concept	Definition
Has identified in	Has_identified_in	User_profile	Publication	Indicates that this profile shares the same publication
Has a friend	Has_a_friend	User_Profile	User_profile	Described the existence of a relationship between two users profiles
Has marked	Has_marked	User_profile	Humor	The user express his mood

The attribute table consists of five columns: the name of the relation (relation), the id attribute (ID attribute), the concept which it is attached (associated concept), the type of the attribute (Attribute Type) and the attribute definition in natural language (description) (Table 2).

Associative relations describe the second type. They connect concepts by relations and links of subsumption. These relations are frequently binary and can have different properties example (functional relationship, transitive relation, etc.)

Table 3 shows relations and consists of five columns: the name of the relation (relation), the ID of the relation (ID Relation), the concepts involved in the relation (Original Concept and target concept) and finally definition of the relation in natural language.

5 CONCLUSIONS

For the purpose of supporting applications dealing with mobility data and requesting further contextual and semantic information about moving objects and their geographical trajectories, this paper offered a generic approach for the modeling of social network users' geographical trajectories. The proposed approach combined three ontologies : Social Network Domain Ontology, Geometric Trajectory Ontology and Geographic Ontology using GeoNames[4] and FAO[2] Ontology.

As future work, we are going to adopt the reasoning mechanisms of OWL-DL to deduce new information and to detect semantic conflicts and gaps that can hold between heterogeneous trajectory data sources. Also, we will adopt an ontological approach to integrate different trajectory data sources in a trajectory data warehouse by using the shared trajectory ontology. This integration will support trajectory-oriented applications dealing with mobility data, enhance the decision making process and allow querying mobility data on the semantic level, revealing then information about the mobile objects activities and behavior.

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