OurMap: Representing Crowdsourced Annotations on Geospatial Coordinates as Linked Open Data

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Abstract. There is an increasing number of initiatives using Web-based mapping systems that rely on crowdsourcing as a collaborative problem-solving and data production model. In these initiatives, large groups of users can collaboratively annotate spatial things on a map. Ideally, these crowdsourcing initiatives should produce Linked Open Data (LOD) to enable people/systems to share structured data and, consequently, improve distributed problem-solving on the Web. This paper presents an approach for producing LOD from crowdsourced annotations on Web-based mapping systems. In this approach, annotations are represented using the Open Annotation data model and they have as target a geospatial coordinate referenced using the geo URI. Moreover, we combine crowdsourced map annotations with semantic Web technologies to enrich maps with semantic information. To demonstrate the feasibility of our approach, we present the OurMap system, which performs the proposed approach allowing the representation of open and semantic annotations associated with geospatial coordinates independently of the Web map interface adopted.

Keywords: Open Annotation, Semantic Web, RDF, Volunteered Geographic Information.

1 Introduction

According to Brabham [1], crowdsourcing is a production model to solve problems based on collective intelligence and knowledge. There are various Web systems adopting this model in order to obtain needed knowledge or service by soliciting voluntary contribution from a large group of Web users. These systems must provide mechanisms for users to collaborate to build the necessary knowledge, and deal with the problems associated with this voluntary collaboration.

There are various Web mapping services available and some of them adopt the crowdsourcing model. In this work, we distinguish two main categories of user's information associated to Web maps: (i) crowdsourcing geospatial data and (ii) crowdsourced map annotations. Crowdsourcing geospatial data refers to generate a

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map using informal social networks and Web 2.0 technologies [2], producing the so-called Volunteered Geographic Information (VGI). OpenStreetMap (OSM) [3], Wikimapia.org and Google Map Maker [4] are well-known initiatives in this category of crowdsourcing on maps. They allow users to add and edit non-movable and long life places (e.g., roads, parks, businesses, schools, etc.).

This paper focuses on the second category of crowdsourcing on maps, which includes initiatives seeking crowdsourcing to overlay annotations onto a backcloth map. Based on the map, any information can be collaboratively geotagged by users. Annotating or tagging is about attaching tags, names, attributes, comments, etc. to a geographical coordinate. In this paper, we adopt the term "map annotations" to refer to the association between the annotated information and its geographical identification.

There are several examples of systems providing social map annotation functionality using urban zone maps backdrop. These systems allow annotating "things" of a specific domain, such as crimes [5], crisis [6], health [7] and human rights abuses [8]. Additionally to identify non-movable and permanent places, these systems seek to classify several "things" on the maps as events that occurred at some time or that have short life cycle, related to, for instance, crimes and disasters.

Social map annotation systems must deal with the problems introduced by the voluntary collaboration for the knowledge construction. In particular, this kind of system may suffer from problems due to voluntary collaboration of a large group of web users, such as the low quality of the generated content [9]. In general, map annotation systems allow users to create annotations without a semantic rigor, contributing to its low quality. Thus, the knowledge collaboratively generated cannot be more easily integrated and interpreted automatically by the systems.

Regarding knowledge representation, there are several studies pointing the advantages of using ontology-based approaches, such as [10], [11], [12] and [13]. Ontologies can be specified as sets of concepts, individuals, relations, instances and axioms that describe a domain [14]. Ontologies can also be part of a database, known as ontological Knowledge Base (KB). These KBs relies on formalizing the representation of knowledge, enabling enhanced information retrieval, data consistency verification, and increasing interoperability. Therefore, the association of semantics with the annotated content can improve the organization and management of knowledge. Particularly important in map annotations, the semantic tagging allows the verification of location consistency on maps. For example, the annotation of a pothole in a street only makes sense if it is annotated on a geographical coordinate near to a street (a pothole could not be annotable at sea, for example).

The lack of openness is another recurring problem in many map annotations initiatives. Several of these initiatives are closed; the user-generated annotations remain inaccessible for third-party systems. Conversely, interoperable annotations facilitates cross-boundary annotations, allowing multiple servers, clients and overlay services to create, discover and make use of the valuable information contained in annotations [15]. There are several initiatives seeking to offer services or publish useful information for the society. Offering interoperable annotations, these initiatives could use the annotations generated by a larger number of users, enriching the knowledge of incidents and improving the mapping and problem solving.

Let us illustrate this in the context of public safety. There are various initiatives allowing users to report security incident in many cities. Initiatives seeking to publish and to analyze security events in a region, state or country can reuse annotations created using the first ones. Moreover, initiatives offering crowdsourcing travel experience, for instance, can reuse/export annotations related to public safety incidents from/to initiatives in the public safety domain.

A recent effort to enable interoperable annotation is in progress by the W3C Open Annotation Community Group [16] that works towards a common, RDF-based, specification for annotating digital resources: the Open Annotation Model (OA). OA follows the Linked Data principles [17]. MapHub [18], a Web portal for georeferencing and annotating digitized historic maps, under development at Cornell University, is one of the few examples of online application that produces open annotations.

The OA model is not sufficient to guarantee the sharing of the knowledge contained in annotations. Different initiatives can adopt different categorization schema for annotations. For example, a system focused on the public safety domain can have different categories for security-related incidents, such as violence, robbery, theft, etc. In its turn, a system in the tourism domain can categorize these terms as security incident only. This high degree of semantic interoperability requires the adoption of high-level ontologies, allowing the knowledge to be shared through different platforms.

From the above discussion, the paper aims to advance the state of art in crowdsourced annotations on Web-based mapping systems through the following contributions:

1. An open representation of map annotations through the OA model in which the targets are geospatial coordinates referenced in the form of geo URI, as recommended by RFC 5870 [19]. Therefore, the annotated "thing" is the geospatial coordinates, rather than resources over Web. Because of the proposed open representation of annotations and the use of geo URIs, the scheme can create Linked Open Data (LOD) that have the potential to be reused by any application based on any Web mapping services.
2. A high-level ontology to represent knowledge about spatially located incidents. This ontology specifies concepts that are common to all incident domains, such as crimes, crisis and health. The knowledge representation language adopted is OWL [20].
3. Finally, a social semantic tagging approach that associates map annotations with individuals kept in a KB. In this approach, users can collaborate to populate the KB with individuals that semantically describe incidents on the map.

Different from current map annotations adopting ontological approaches, our proposal offers more than a simple semantic tagging of places. Our proposal offers a way to associate spatial things with semantic entities stored in a KB populated collaboratively by the users [21]. When creating map annotations, users implicitly generate individuals to be instantiated in the KB. More specifically, during a map annotation the user identifies the category of annotation, i.e. the class in the ontology, and specifies the property of the individual to be instantiated in the KB. In the sequel, this newly created annotation is semantically tagged with the URI of this instantiated individual (rather than concepts). For example, a map annotation can have a semantic tag that relates a geographic coordinate of a bus stop to an individual in the KB of the abstract concept `Bus_stop`. The KB can specify a link between this individual with an individual of the abstract concept `Road`, which in turn can be associated with an individual of the abstract concept `Suburb`.

Thanks to the inference engines (reasoners), possible inconsistency on KB can be detected. In the previous example, consider that the ontology specifies that a `Bus_stop` must be associated with a `Road`. Consequently, a bus stop can be defined only in "places" that can be associated with a road. Moreover, information retrieval is improved by the ability to perform searches that exploit the ontology to make inference about data (using SPARQL [22]). For instance, it is possible to retrieve all bus stops in a particular suburb.

Using the proposed open and semantic representation for incidents, we intend to contribute to different initiatives in social annotations on maps, so it can support each other by exchanging information about incidents in different domains.

To demonstrate the feasibility of our approach, a prototype implementation was developed and tested. This proof-of-concept prototype, called OurMap, allows users to annotate both permanent places and incidents that occur on places at some time. Its architecture has been defined to provide a loose couple relation between Web mapping services and the OurMap annotation service. Therefore, OurMap relies on the services offered by existing Web mapping services, such as OSM and GoogleMaps API, so annotations can be related to a geographic coordinate on a map.

The rest of this paper is organized as follows. Section 2 presents the Open Annotation (OA) data model. Section 3 points out the main requirements for annotation of incidents on maps, and presents the related work. In Section 4 the proposed open representation of incidents on maps is described. Section 5 presents OurMap, our incident map annotation tool adopting our open representation for incidents. Finally, conclusions and future work are presented in Section 6.

2 Open Digital Annotation

Digital annotations allow us to associate content with other resources. There are various motivation for creating annotations. In the context of this work, the annotations are the way used by the users to report incidents or to identify a place on maps. In several systems, the user-generated annotations remain inaccessible for third-party systems. The adoption of open annotation data models allows expressing annotations in a way that they can be shared between different annotation systems, what is particularly important to crowdsourcing initiatives in numerous domains. We consider that the performance in problem solving can be improved if different crowdsourcing initiatives in the same domain share their annotations.

There have been some attempts to establish open data model for annotations, including Annotea [23], Annotation Ontology [24] and the Open Annotation Model [25]. The W3C Open Annotation Community Group aims to conciliate these last two proposals through a common, RDF-based, specification for annotating digital resources: the Open Annotation (OA) data model [16].

In the OA data model, an annotation expresses the relationship between two or more resources, and their metadata, using an RDF graph. The OA model defines a namespaces (http://www.w3.org/ns/oa) for its classes and properties [25].

Fig. 1 presents two annotations (`A-1` and `A-2`) specified with the OA model and therefore instances of `oa:Annotation`, defining relationships between two or more resources. These resources are members of the classes `oa:Target` and `oa:Body`, in which targets are resources being annotated and bodies are comments or other descriptive resources about a target. The relationship `oa:hasTarget` associated with `A-1` defines `T-1` as target of `A-1`. This annotation has two associated bodies (with `oa:hasBody`): `B-1` a descriptive resources about `T-1`; and `Tag1`, which tags semantically `T-1`. In addition to bodies and targets, an annotation can have many properties such as author (`oa:annotatedBy`), title (`dcterms:title`) and date of creation (`oa:annotatedAt`). Moreover, [25] suggests that each annotation should have at least one `oa:motivatedBy` relationship to an instance of `oa:Motivation`. It is important to understand the reasons for the creation of annotation. For instance, the motivation of `A-1` is `oa:tagging`, identifying that this annotation adds a Tag on the target resource (`T-1`). Annotation `A-2` is a questioning about annotation `A-1`.

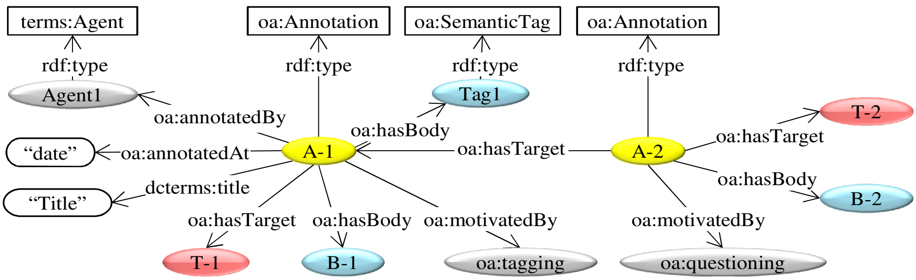

Fig. 1. Illustrating the OA Model

3 Annotation of Incidents on Maps

This section presents the related work, including the identification of some important aspect of Web systems that allow crowdsourced annotation of incidents on maps.

3.1 Describing Incidents

The popular map annotation systems, such as Google Maps Maker, Wikimapia and OSM, allow users to annotate only non-movable places that exist at the time when the annotation is being created. Incident annotations have different characteristics than annotations of non-movable places:

- **Temporal Characteristics**: the reporter of an incident can know the instant or the time interval in which the incident occurred, or he may not know when it started or ended. Moreover, the reporter just may have observed at a given time. Therefore, an incident annotation system should provide flexibility in positioning the incident in time.

- **Location Characteristics**: differently of non-movable places, many incidents may not have a well-known location. Therefore, the system should allow the location to be described not only by precise geographical coordinates, but also by generic spatial relations [26], as to the left of, right of, behind, in front, around, inside and out.
- **Thematic/Semantic Information**: to be more precise and useful, the reporting of an incident should define the type or category of the incident. The annotation system must adopt vocabularies of types of incidents dependent on the application domain.

Regarding the temporal characteristics, in general the existing systems allow users to specify the start and end date/time of incidents (a time interval), as adopted in Ushahidi [6] and Wikicrimes [5]. However, time imprecisions and distinction of period of observation are not supported. Considering the spatial characteristics, the current annotation systems allow the reporter to accurately express the location of the incident (geographic coordinates or well-defined region). Usually this way of location cannot represent the precise location of the incident, which may lead to wrong conclusions.

In terms of thematic information, the current incident/event annotation systems adopt prefixed categories of incidents (thematic information). However, unlike some initiatives of production of VGI, few incident annotation systems offer features of semantic mark-up on maps, making the interpretation and reuse of its content more difficult.

3.2 Open Annotation of Incidents

In general, Web-based solutions seek to identify events/incidents adopting implementation-dependent representations of annotations, and consequently these remain inaccessible for third-party systems. In this case, the crowdsourced information cannot be easily reused by other initiatives.

Wikimapia, a popular GoogleMaps API-based interactive Web map system offers an open-content crowdsourced mapping service, via the Wikimapia API (http://wikimapia.org/api/), allowing third-party systems to receive data from Wikimapia project in various formats (XML, KML, JSON, JSON-P and binary). Similarly, OSM provides a RESTful API in which read and write queries can be formulated in OSM XML format. However, Wikimapia and OSM allow creating annotations only in non-movable places that can be categorized using a fixed category list.

In the context of incident/event annotation systems, the majority of initiatives do not adopt open representation. For instance, [5] and [7] are based on the Google Maps API (http://code.google.com/apis/maps/), and the map annotations are not published under an open content license and cannot be reused in other services. Conversely, Ushahidi and PublicSafetyMap.org offer data in RDF/XML.

Ushahidi is an open source platform that has been designed for geo-located responses to crisis. This platform allows users to create structured annotations that can be categorized and associated with photos and videos. The Ushahidi REST API supports retrieval and report submission of annotations in both XML and JSON output formats. However, Ushahidi (and Wikimapia) does not adopt standardized data model so that these data can be easily shared between platforms. As presented in Section 2, the OA Model is a solution.

In the map annotation domain, MapHub demonstrates how to apply the OA Data Model in the context of digitized historic maps. As already pointed out in this work, we demonstrate how to apply the OA Data Model in the context of map annotations.

In this work, we propose an open representation of map annotations through the OA model in which the targets are geospatial coordinates referenced in the form of geo URI. As previously described, this approach allows users to annotate "things" on geospatial coordinates, rather than resources over Web.

3.3 Knowledge Representation

In addition to adopt open representation of annotations, map annotation systems should allow the semantic tagging of these annotations. This kind of tagging can contribute in the following three areas [27]:

- **Knowledge Representation Sophistication**: Ontologies allow robust representation of entities and relationships that shape tagging activities.
- **Facilitation of Knowledge Exchange**: Ontologies enable knowledge exchange among different systems and users by providing shareable conceptualization.
- **Machine-Processable**: Ontologies and Semantic Web Technologies enable to represent the semantics of data in a machine-processable way, which can be used for data analysis and concept recognition, for reasoning processes and for semantic search.

The GeoNames ontology [28] (available on OWL) models geospatial semantic information. This ontology makes it possible to add geospatial semantic information about places in the GeoNames database. GeoNames is more than a simple semantic tagging of places; it allows users to express properties about named places. Moreover, its data is available through numerous Web Services and also published as linked data. However, GeoNames ontology specifies only general properties valid for all concepts; class-specific data and object properties are not supported.

The OSM project adopts a tagging system that allows the map to contain unlimited data about its elements. Therefore, OSM adopts a metadata (i.e. data about data) provided in the form of `key="values"` pairs. This tagging scheme is being developed into taxonomy of real-world feature classes and objects [3]. The OSM project provides a RESTful API where read and write queries can be formulated in OSM XML format. Similar to the previous proposals, OSM allows only creating annotations in non-movable places that can be tagged using the OSM tagging scheme [3]. The LinkedGeoData (LGD) project [29] provides an integrated and interlinked geographic dataset for the Semantic Web. The majority of this data is obtained by converting the OSM data and is available as an RDF knowledge base according to the Linked Data principles.

MapHub allows users to annotate historic maps and connect these annotations with web resources via semantic tagging. These semantic tags are suggested for the creators of annotations by querying open data sources such as Wikiminer [30] or GeoNames.

All previously cited systems do not aim to specify incidents semantically on the map. In this context, there are some initiatives proposing event/incident ontologies that have potential to be used in the context of map annotations. In [31], the authors provide an overview and a comparison about the existing event ontologies and the way used by each of them to model occurrence time and place.

The Event Ontology (EO) [32] has been developed to be used with music-related ontologies, but it offers high level and minimalist event model that has been widely used by LOD community. EO defines the Event class, an arbitrary classification of a space/time region. An event may have a location, a time, active agents, factors and products. The property time defines the event temporal features and is defined through the class `time:TemporalEntity`, from OWL-Time ontology (http://www.w3.org/2006/time#). Location is expressed using the class `geo:SpatialThing`, from the World Geodetic System 1984 (WGS84) [33]. EO doesn't allow expressing incidents that don't have a known and precise location, only using generic spatial relations with geospatial coordinate or named places.

DOLCE+DnS Ultralite (DUL) [34] is a lightweight ontology that provides a set of upper level concepts that can be the basis for easier interoperability among many middle and low-level ontologies. In this ontology, the Event class is any physical, social, or mental process, event, or state. DUL allows specifying dates for an event (using the datatype property `hasEventDate`) or the temporal interval can be instantiated, through TimeInterval class, and related to an event instance via the `isObservableAt` object property.

The Event Model-F ontology [35] is a formal model for events built on top of DUL. It supports to represent time and space, objects and persons, mereological, causal, and correlative relationships between events, and different interpretations of the same event. The parameter `F:TimeParameter` describes the temporal region when the event happened, being possible to define an instant or a time interval, and the parameter `F:LocationParameter` makes it possible to model location via WGS84 vocabulary, using two properties, for latitude and longitude.

The Simple Event Model (SEM) [36] ontology has been defined to model events in various domains. This ontology considers the loose definition of events. Its definition of time is divided into seven `sem:hasTimeStamp` properties, one of which is for temporal values, two for time intervals and four for uncertain time intervals. In SEM there are symbolic places with location defined by various structures, like `georss:point`, `wgs84:lat` and `wgs84:long`, or `rdf:XMLLiteral` pointed by `georss:where`. Like EO, SEM does not allow to express generic spatial relations.

In this work, we propose an Incident Ontology that groups features that are not found together in the above ontologies. Our requirements include the need of a generic Incident class that allows a loose definition of temporal and location characteristics of incident. The time property from SEM corresponds to our necessity on defining unknown occurrence time and uncertain time intervals for an event.

However, we need an ontology that also supports the usage of a spatial relationship between incidents as data property.

The present proposal adopts the OA model to represent open annotations and OWL for knowledge representation. Different from previous work using semantic tags in map annotations, our approach allows the generation of an ontological knowledge base formalizing the representation of information generated collaboratively during the annotation process. It also allows various systems to make use of the produced annotations, and make possible to use different tools for semantic search, inference, and viewers to OWL representation.

4 Representing Open Annotations on Maps

The purpose of the OA model is to be a common specification for annotating digital resources. In this section, we propose the use of the OA model to represent digital annotation on geospatial coordinates instead of on web resources. In our proposal, the targets of map annotations are geographic locations. The annotation is represented unrelated (e.g. URL pointing a geographic coordinate specific of the web mapping system), making it completely reusable by different map annotation tools.

Moreover, this section presents a semantic approach to represent the collaboratively generated information during the map annotation process.

4.1 Geographic Locations as Targets of Map Annotations

Providing open annotations in Web-based map annotation systems requires special attention in the location identification. We consider important that this identification can be represented independently of any Web resource (like a specific URL in a Web mapping system). The geo URI scheme is a step in that direction of an independent, compact, and generic way to refer to a physical geographic location [19]. The geo URI identifies geographic location (physical resources) through the coordinate reference system WGS-84. The scheme offers textual representation of spatial coordinates of locations.

In this work, we propose the use of geo URIs to identify targets in map annotations represented using the OA data model. Several systems adopting RDF representations for annotation make use of the Basic Geo Vocabulary (http://www.w3.org/2003/01/geo/#vocabulary) to identify location. However, this vocabulary allows the identification to be made as properties and the annotation targets and bodies are Web resources. Using geo URIs and the OA data model, the targets of a map annotation can be physical resources, i.e. geographic locations, increasing the independence of the annotations from applications.

4.2 Incident Ontology

As presented in Section 3, there are several initiatives to establish ontologies that have potential to be used in the context of map annotation. However, none of the analysed ontologies offers a loose definition of temporal and spatial characteristics of incidents. With this purpose, we propose the OurMap ontology, an upper level ontology for Incidents.

Another important point to be considered in crowdsourcing systems is the difficulty to ensure the quality of information voluntarily generated by the community [9]. A semantic approach should guarantee a minimum of semantic consistency in terms of the location of this information. By the lack of an ontology generic enough to cover the basic concepts related to geographical annotations of incidents associated with elements of community life, was defined a high-level ontology, named OurMap.

A simplified view of the OurMap ontology is represented on Fig. 2. The two main concepts are `Place` and `Incident`, both subclasses of `geo:SpatialThing` defined by WGS84. `Place` (http://schema.org/Place) represents something immobile or a location. `Incident` is any incident. The `AdministrativeArea` class (http://schema.org/AdministrativeArea) is any geographic region under the jurisdiction of a particular government, having as subclasses `Country`, `State` and `City` (all defined in http://schema.org). We defined two subclasses of `Place`: `Suburb` and `Road`.

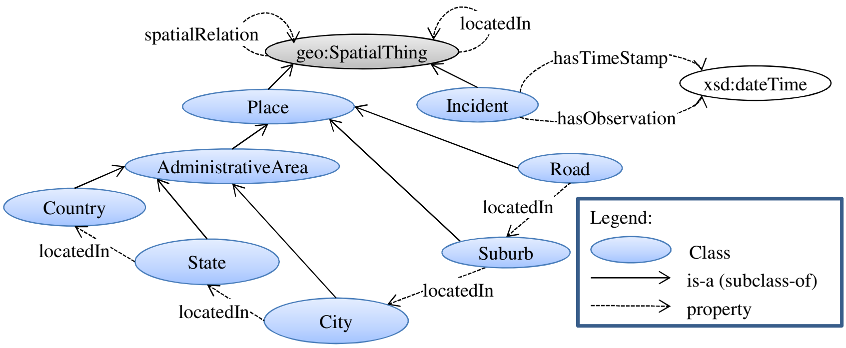

Fig. 2. The OurMap Ontology

The property `locatedIn` allows specifying location relationships between different spatial things, including places. Ontology OurMap defines that `Road` individuals have a `locatedIn` relation with `Suburb`, `Suburb` with `City`, and so on. This ensures a minimum consistency of administrative places, streets and neighbourhoods.

`Incident` may also have a location relation (`locatedIn`) with any other `SpatialThing`. Moreover, an `Incident` may have a generic spatial relation (`spatialRelation`) between other `SpatialThing`: `under`, `isinside`, `encloses`, `near` and `over`. We defined six sub-relations of `near`: `behind`, `beside`, `rightOf`, `leftOf`, `adjacent` and `inFrontOf`. Finally, we defined a sub-relation of `adjacent` called `onTop`. These relations have logical characteristics, like symmetry and transitivity, in order to allow proximity inference between incidents and places.

The data properties `hasObservation` and `hasTimeStamp` of class `Incident` define the instant or time interval of the occurrence and observation of the incident, respectively. Both properties have as literal type `xsd:dateTime`. `hasObservation` used to express the instant of observation of the incident, and its two sub- properties, `hasStartObservation` and `hasFinishObservation`, allow defining intervals of observation. `hasTimeStamp` defines the instant of the incident's occurrence, and its two sub-properties, `hasStart` and `hasFinish`, allow defining a time interval. In its turn, the latter two have sub-properties that allow specifying imprecise time intervals (`hasStartAfter`, `hasStartBefore`, `hasFinishAfter` and `hasFinishBefore`). We also defined SWRL rules [37] to assign values to properties `hasStartBefore` and `hasFinishAfter` in incidents with instants or time intervals of observation and without a known time of occurrence. These rules express the consequence that if the incident is observed at a given instant, the beginning of the incident is prior to that moment, and the end is later.

4.3 Creating New Incident and Places Classes

Thanks to the possibility of reuse existing ontologies, it is possible to extend the OurMap ontology to specific domains. All domain-specific categories of incidents or places (possibly defined in other ontologies) that can be annotated by the user on the map must be defined as subclasses of `Incident` and `Place`, respectively. Moreover, each new subclass can have specified location restrictions. As previously presented, the latest is important to ensure the location consistency.

For instance, consider the use of OurMap ontology in the domain of public transportation. In this case, it is possible to use OTN Ontology [38] to specify objects in this domain. All OTN classes classifying places or incidents that can be annotated by the user on the map must be defined as subclass of `Incident` and `Place`. For instance, if incidents can be reported on (or with spatial relations between) `OTN:Stop_Point`, this class must be declared as a subclass of `Place`. Moreover, if the location of objects of class `Stop_Point` is in roads, this class must be defined as a subclass of concepts that have the relation `locatedIn` set to `Road`. This latest allows maintain the location consistency of the crowdsourced annotations.

There are some few Incident/Event ontologies for specific domains. Therefore, because of our semantic approach, it is necessary to create a hierarchy of subclasses of `Incident`. For each subclass, it can be specified restrictions on the location of places. For example, a subclass of incident called `Pothole` (hole in the street) could be specified so that individuals of this class must have a location relation with a `Road`.

4.4 Associating Semantics to Annotations

There are several studies pointing out the advantages of using ontology-based approaches in the Geographic Information Systems (GIS) domain ([10], [11]). These advantages are well known in the Semantic Web area as a possibility to integrate, share and analyse geospatial information. Various ontologies proposed for GIS aim to specify geospatial concepts [39] and [40]. These ontologies specify concepts on the GIS domain, which can be applied to systems that implement the concept of the crowdsourcing in the construction of cartographic maps (so-called crowdsourced maps).

In general, the map annotation systems semantically tag annotations by tagging resources available in external systems, like DBPedia (http://dbpedia.org) and GeoNames. In this work, we propose maintain a KB representing all knowledge explained by the crowdsourced annotations. In this KB, places and incidents are represented as individuals. These objects are expressed as URIs that are used to tag semantically incidents and places.

Fig. 3 illustrates how objects in the KB are used to tag two annotations. A user created `A-3` to identify a bus stop in a specific spatial coordinate. During the creation of this annotation, a `Stop_Point` individual is generated in the KB. Note that this annotation is allowed because its geographic location `(geo:-27.599217,-48.519018)` is near of a road (as specified in the ontology), called Delfino Conti Street situated in the Pantanal neighbourhood of the city of Florianópolis. `A-4` represents a robbery near this bus stop. This robbery is represented in the KB by the *Incident* individual.

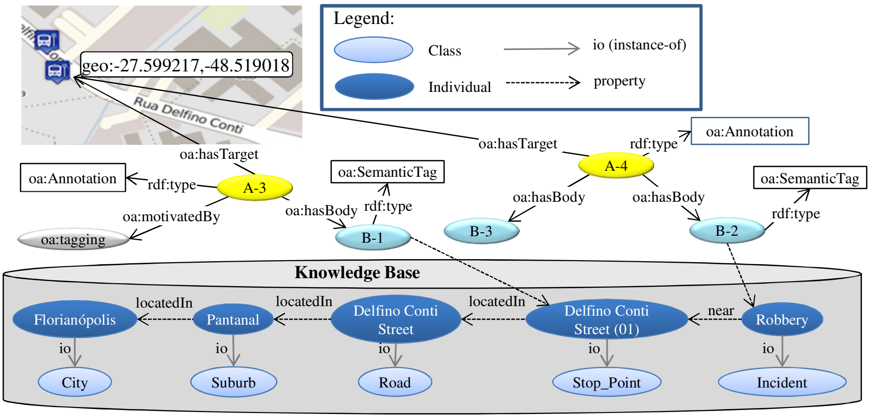

Fig. 3. Semantic tags and the knowledge base

As presented in Section 2, semantic tags in the OA data model are expressed as a URI, the body of the annotation is the URI of the tagging resource. The `oa:SemanticTag` class is associated with this tagging resource. In our proposal, `A-3` and `A-4` have bodies representing semantic tag expressed as URIs identifying the `Stop_Point` individual and the `Incident` individual (or a domain-specific subclass), respectively.

Rather than tagging `A-3` and `A-4` as `Stop_Point` and `Incident` as provided by the current systems, we tag these annotations referencing individuals of these classes. Tagging annotations with individuals in the KB allows us to consider relationships between individuals (as defined in the ontology) and check consistency in terms of location. The maintenance of a KB of incidents allows us to build a repository of information on which more advanced and efficient semantic search can be achieved. Moreover, inference process can be used to generate new knowledge and to verify consistency of the ontology.

5 OurMap: A Map-Based Digital Annotation System

This section presents a general view of our proof-of-concept prototype, called OurMap, implementing the proposal of representing open and semantic annotations of incidents on maps. The main purpose here is to demonstrate the crowdsourcing approach to generate annotations of places and incidents on maps and the management of a knowledge base specifying the knowledge collaboratively generated during the annotation process.

The proof-of-concept prototype OurMap is implemented with Java, OpenLayers [41], OSM geocoding system [42], Jackson Json API to process the information received from the geocoding system. The Jena API [43] was used for programming environment for the semantic aspects

5.1 Customizing OurMap

OurMap can be customized for a specific domain of incidents and places by importing ontologies describing the domain-specific incident and place categories. For instance, in our tests we imported the OTN ontology customizing OurMap for the Public Transportation domain. After importing ontologies, it is necessary to specify the classes whose individuals can be identified on the maps during the annotation process (individuals that will be kept in the KB). Fig. 4 shows the interface used to specify annotable classes. This interface allows specifying the icon associated with the places and incidents, and the allowed place of occurrence.

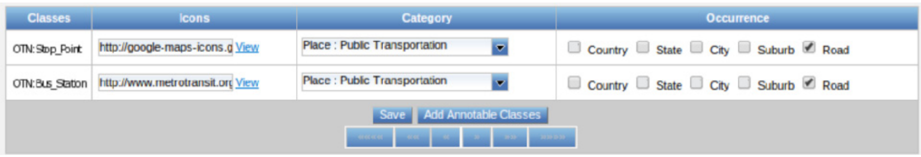

Fig. 4. Specifying Annotable Classes

5.2 Creating Annotations

Annotations can be done in two ways: (i) manually, by users on OurMap User Interface or (ii) automatically, by running mapping scripts to get the open data made available by other initiatives and generate annotation in OurMap. In the proof of concept implementation, we created a mapping script to generated individuals in the KB representing all neighbourhoods, streets and bus stops of the city of Florianópolis from the OSM database. Fig. 5 presents the interface for incident report near a bus stop in which users can describe the spatial and temporal characteristics of the reported incident.

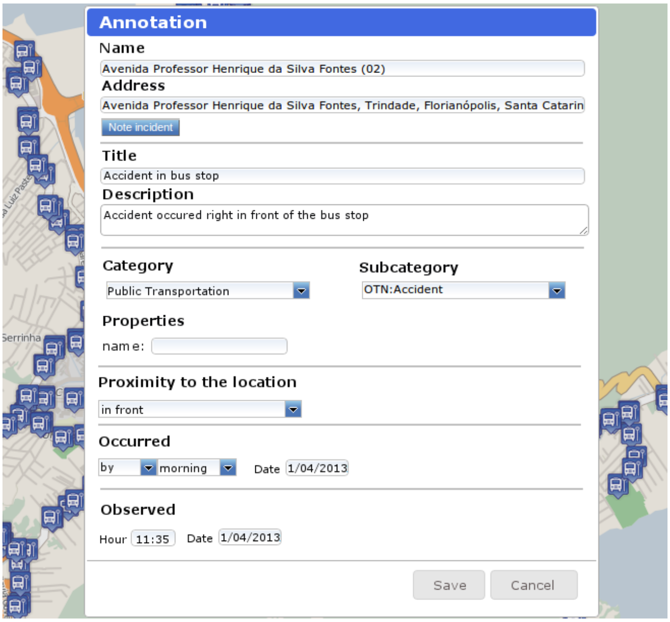

Fig. 5. Incident Report

5.3 Accessing Open Data

We developed a public API called OurMap RESTful Web API, in order to provide the knowledge voluntarily generated via OurMap system. Through this API, it is possible to have access to all data in both the annotation base as in the KB. This API allows the information retrieval by simple requests made through HTTP methods, with the passing of parameters that define the search for information. These parameters refer to location, time and category of annotations so that is possible to recover only relevant information. For example, it is possible to seek the assaults occurred in the suburb Pantanal, at 11 pm. on April 10, 2013.

The OurMap API also supports the language SPARQL in order that more complex queries may be done. In this way, you can make queries relating to different criteria, obtaining even more accurate and complete results than those from HTTP methods. For example, you can search assaults that occurred next to bus stops, in the suburb Pantanal, between 11 pm. and 4 am. every night of last month.

6 Conclusion

The crowdsourcing model of geospatial data is already being used by several communities to allow users to assist in the voluntary production of information. This paper proposes an open representation of place and incident annotations in digital maps following the principles of LOD. For this representation, we adopted the OA scheme and the geo URI to identify geographic coordinates independently of Web map systems. In addition, the collaborative knowledge created during the annotation process is kept in ontological knowledge base. Represent knowledge using the OWL Language allows to perform information search and knowledge discovery based on ontologies, in order to enable improved decision-making.

A proof concept prototype of our OurMap system is presented. This prototype adopts the semantic approach for Incident reports on maps proposed in this paper. Moreover, it uses the open representation of digital annotation proposal.

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