

Towards a smart city ontology

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Abstract—The rapid development of semantic Web and exponential growth in the use of the ontology in the field of smart cities, along with World Wide Web, make new and different multi-dimensional character of the smart cities a possibility, in which data is collected from various distributed systems. Consequently, in this paper, we exploit the concept of semantic Web for designing a new smart city ontology that is considered as a system of systems. Such ontology is beneficial for both the citizens and the administrators as it allows interoperability among different systems and frameworks.

Keywords—Smart cities; Semantic Web; Linked Open Data; DBpedia; Ontology.

I. INTRODUCTION

The rapid development of semantic Web and exponential growth in the use of the ontology in the field of smart cities, along with World Wide Web, make new and different multi-dimensional character of the smart cities a possibility, in which data is collected from various distributed systems. Semantic Web technologies have an extremely high potential and practical impact by providing the ground for new e-services within the ecosystems of cities [1]. Using technologies of Semantic Web, we can develop a set of solutions that might work in parallel with the Internet-of-Things as well as embedded systems; hence, they provide new opportunities for social media collaboration and collective intelligence. Semantic Web technologies enable to put into practice the Open Government's Data (OGD) principles of transparency, participation and collaboration [2, 3], in the purpose to integrate citizen within the smart city paradigms. Popular private and public stocks of the semantic web include, among others, DBpedia and Geonames Dbpedia [22], a large reference dataset of structured information extracted from Wikipedia [23] providing encyclopedic knowledge about a multitude of different domains. This structured information is then made available on the World Wide Web [4] by using a package of APIs.

Geonames [24], a data source exclusively for geographic data and cartographic. His database contains over 10 million geographical names and consists of over 9 million unique

features whereof 2.8 million populated places and 5.5 million alternate names. The data are automatically extracted from freely available Wikipedia dumps where each single article in Wikipedia is represented by a corresponding resource URI in DBpedia. In this case the URI is considered as unique identifier that makes content addressable on the Internet by uniquely targeting elements. Several RDF statements are generated for each resource by extracting information from various parts of the Wikipedia articles [5].

All available versions of DBpedia describe 24.9 million things, out of which 16.8 million overlap with the concepts from the English Dbpedia. The English version of the DBpedia knowledge base currently describes 4.58 million things, including 1,450,000 persons, 735,000 places, 123,000 music albums, 87,000 films 19,000 video games, 241,000 organizations (including companies and educational institutions), 251,000 species and 5,600 diseases [21].

RDF (Resource Description Framework) [6] builds on XML to better manage semantic interoperation. RDF is a data model designed to standardize the definition and use of metadata in order to better describe and handle data semantics. Each document written following RDF format is viewed as a set of triples (subject, predicate and object) that can be distributed, stored and treated in scalable triple-stores.

The DBpedia Ontology [25] has been manually created based on the most commonly used infoboxes within Wikipedia (see Fig.1). The ontology covers 685 classes [26] which form a subsumption hierarchy and are described by 2,795 different properties [27]. The DBpedia Ontology currently contains about 4,233,000 instances. We can also download an OWL file [28] containing all classes and properties as they are currently defined.

Fig. 1. Ontology of dbpedia for smart cities.

Ontology Classes

- owl:Thing
 - Activity (edit)
 - Game (edit)
 - BoardGame (edit)
 - CardGame (edit)
 - Sales (edit)
 - Sport (edit)
 - Athletics (edit)
 - Boxing (edit)
 - BoxingCategory (edit)
 - BoxingStyle (edit)
 - HorseRiding (edit)
 - TeamSport (edit)
 - Soccer (edit)
 - Agent (edit)
 - Deity (edit)
 - Employer (edit)
 - Family (edit)
 - NobleFamily (edit)
 - Organisation (edit)
 - Broadcaster (edit)
 - BroadcastNetwork (edit)
 - RadioStation (edit)
 - TelevisionStation (edit)

Each class is defined by a `{{Class}}` template [29] in a wiki page in the `OntologyClass` namespace followed by the class label. For example, the `Person` class is defined in the page: <http://mappings.dbpedia.org/index.php/OntologyClass:Person>.

The corresponding code has the syntax that is presented in Fig. 2.

Fig. 2. Template of OntologyClass.

```

{{Class
| labels =
| {{label|en|person}}
| {{label|de|Person}}
| {{label|fr|personne}}
| ...
| rdfs:subClassOf = Agent
| owl:equivalentClass = foaf:Person,
                        schema:Person
}}
```

- Labels: should be defined to provide a human-readable version of a class name.
- Comments: should be defined to provide a human-readable description of a class.
- `rdfs:subClassOf`: is used to state that all the instances of one class are instances another.
- `owl:equivalentClass`:
- `owl:disjointWith`:

The same thing, each property is defined by a `{{property}}` template [30] in a wiki page in the `OntologyProperty` namespace followed by the property label. For example the

`LocationCity` property is defined in the page: <http://mappings.dbpedia.org/index.php/OntologyProperty:LocationCity>

The corresponding code is described by the syntax that is illustrated in Fig. 3.

Fig. 3. Template of OntologyProperty.

```

{{ObjectProperty
| labels =
| {{label|en|location city}}
| {{label|fr|situé dans la ville}}
| rdfs:domain = Organisation
| rdfs:range = City
| rdfs:subPropertyOf = location
| comments = {{comment|en|City the thing
              is located.}}
```

- Labels: should be defined to provide a human-readable version of a property's name.
- Comments: should be defined to provide a human-readable description of a property.
- `rdfs:domain`: is used to state that any resource that has a given property is an instance of the stated class. If left empty, `owl:Thing` is assumed.
- `rdfs:range`: is used to state that the values of a property are instances of the stated class. If left empty, `owl:Thing` is assumed.
- `rdfs:subPropertyOf`: defines that the property is a subproperty of some other property.
- `owl:equivalentProperty`:
- `owl:propertyDisjointWith`:

Recently, the concept of smart cities is emerged in the international context [7], with the purpose of achieving the objectives established by the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, and by the Kyoto Protocol in 1997. There are several definitions of the smart cities, here, we can give some of them as follows: smart cities can be identified and classified according to six main dimensions, namely, Smart Economy, Smart People, Smart Governance, Smart Mobility, Smart Environment and Smart Living [8].

Caragliu [9], defined smart cities as: A city can be defined as 'smart' when investments in human and social capital and traditional (transport) and modern (ICT= Information and Communication Technologies) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance. According to IEEE (Institute of Electrical and Electronics Engineers), "A smart city brings together technology, government and society to enable the following characteristics: a smart economy, smart mobility, a smart environment, smart people, smart living, and smart governance" [10].

In this work, we present a new smart city ontology that focuses on the standard of the semantic Web technologies. This ontology is beneficial for both the citizens and the administrators as it allows interoperability among different systems and frameworks.

The rest of this paper is organized as follows. Section 2 describes the related work. Section 3 introduces the proposed ontology for smart cities. Section 4 gives a sample of application. Finally, section 5 concludes the present paper.

II. RELATED WORK

The paradigm of smart city [11] has begun to spread in academic and industry fields, several solutions have been proposed to improve the quality of life of citizen. These solutions have been investigated and implemented in the web 2.0 context; we can cite:

The project SeeClickFix [31] has been created in September 2008, his main goal is to provide the best tools for residents and governments to communicate for all sizes, populations, and budgets. All users may add comments, suggest resolutions, or add video and picture documentation.

At the same time, FixMyStreet [32] has been developed in 2008 to enable iPhone users to report problems using their phones. FixMyStreet [12] was one of the first citizen-driven systems for road maintenance and general public service improvement.

IBM [33] Smarter Cities launched in 2009 [13], it is an initiative of IBM Smarter Planet, created to provide hardware, middleware, software and service solutions for city governments and agencies.

Citizens Connect [34] launched in 2009, Residents report public issues directly from their smart phones into the City's work order management system.

PDX Reporter is a new way to interact with the city concerning problems or issues with publicly maintained infrastructure. The application is compatible with Android phones running 2.1 or higher and may be downloaded for free from the Android Marketplace.

Cisco [35] launched in 2011 the Global Intelligent Urbanization initiative to help cities around the world using the network as the fourth utility for integrated city management, better quality of life for citizens, and economic development.

Microsoft launched in 2013 the CityNext's [14, 36] platform provides citizens, businesses, and government employees including maintenance workers, safety inspectors, case workers, and police officers.

In the last few years, several works tried to focus on Semantic Web technologies for extending and integrating smart city data systems [3]. Among them we can mention:

In [15], authors present their semantic model to describe the sensor streams, demonstrate an annotation and data distribution framework and evaluate their solutions with a set of sample datasets.

[16] Proposed their approach in building semantic models for consumption in assembling large IT (Information Technologies) solutions in cyber-physical (Smarter Cities) domains. The result, called SCRIBE, is a large-scale semantic model for Smarter Cities based on data gathered from cities worldwide.

In [17], the Linked Stream Middleware (LSM) has been developed as a platform that brings both the live real world sensed data and the Semantic Web. It provides many functionalities such as: wrappers for real time data collection and publishing; a web interface for data annotation and visualisation; and a SPARQL endpoint for querying unified Linked Stream Data and Linked Data.

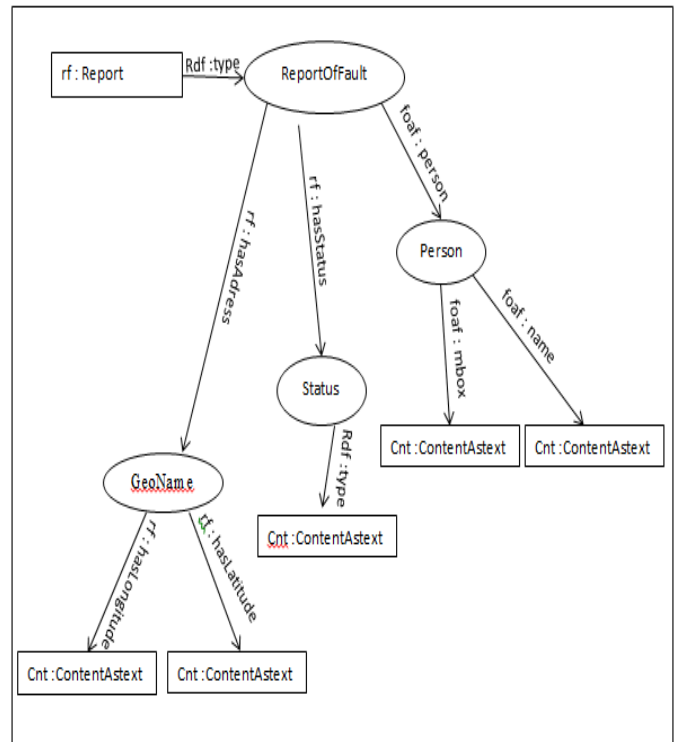
The work presented in [18] is based on collecting, enriching, and publishing LOD for the Municipality of Catania in the context of the Italian Smart Cities project PRISMA.

III. SMART CITY ONTOLOGY

The notion of ontology is introduced as a formal description of concepts that includes classes, proprieties of each class, and restrictions on slots.

In this section, we present a design of an ontology for smart cities which enables interoperability among different systems and frameworks. The first class is called ReportOfFault in which the person who is responsible for detecting and informing the administrator is defined. The second class is called status, which provides status of fault like started, repairing or finished. Fig. 4 shows the ontology containing those elements. It is noted that this ontology is developed based on Open Annotation Core Data Model [37].

Fig. 4. Ontology for smart cities.



To establish a connection between the proposed ontology and DBpedia, we define the class ReportOfFault as subclass of the main class of DBpedia, namely, owl:Thing (see Fig. 6).

Before editing the ontology schema, the following steps are required:

- An account on wiki must be created at : <http://mappings.dbpedia.org/>
- Editor's rights must be solicited at : dbpedia-discussion@lists.sourceforge.net

After creating an account and requesting the rights to edit the DBpedia ontology, we implement our ontology by methods previously shown. Then, we build all the classes and properties. For instance, the class person can be implemented as shown in Fig.5.

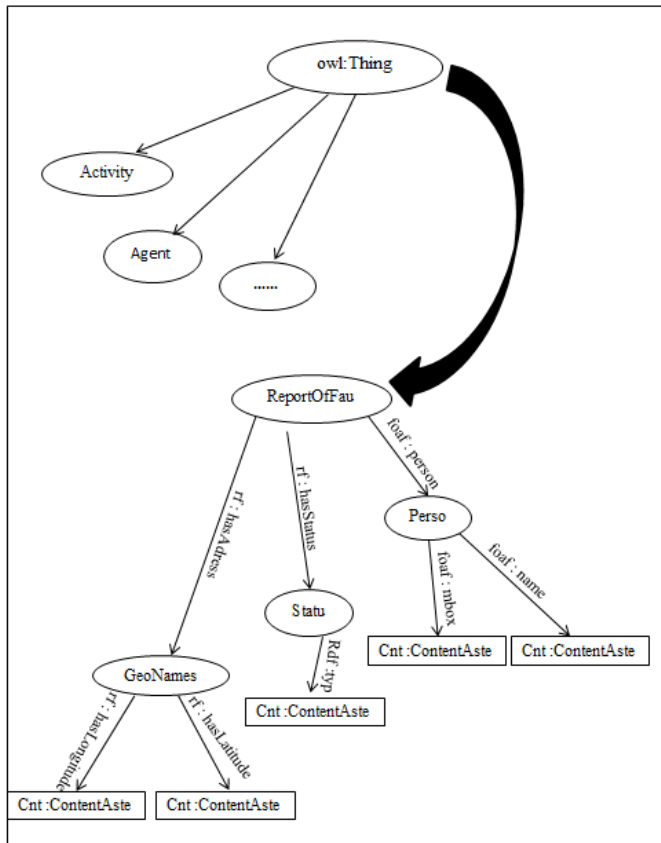
Fig. 5. Person class.

```

{{Class
| labels =
{{label|en|person}}
{{label|de|Person}}
{{label|fr|personne}}
{{label|ar|شخص}}
| rdfs:subClassOf = ReportOfFault
| owl:equivalentClass = foaf:Person
}}

```

Fig. 6. Linking the proposed ontology with DBpedia.



In the same way, we define the rest of the classes. The main class namely, ReportOfFault has a specific implementation, thus, we must define it as subclass of owl:Thing (see Fig. 7).

Fig. 7. ReportOfFault class.

```

{{Class
| labels =
{{label|en| ReportOfFault }}
| rdfs:subClassOf = owl:Thing
}}

```

The code presented in Fig.8 allows the definition of the property hasStatus.

Fig. 8. HasStatus propriety.

```

{{ObjectProperty
| labels =
{{label|en|location city}}
| rdfs:domain = ReportOfFault
| rdfs:range = Status
| comments = {{comment|en|the property
between Status and ReportOfFault.}}
}}

```

In the same way, we define the rest of the properties.

IV. SAMPLE OF APPLICATION

For reporting or detecting any issues in cities, the citizen can begin by introducing his: e-mail first name and geographical localization related to issue (latitude and longitude). The localization is automatically taken by using the Geographic Information System (GIS). We used also the mapping service provided by Google, because it is considered to provide to the end user simplicity, immediacy, accessibility, responsiveness [19, 20]. After that, the user may send an e-mail to administrator for alerting any problem in neighborhoods as shown in Fig. 9. To avoid spams, the administrator publics must control the actual status information sent by the citizen. If the information sent by citizen is correctly, the report is forwarded to the municipal public relations office, which identifies the office responsible to manage and resolve the problem.

Fig. 9. Detecting the fault by the citizen.

Here, we describe the methods and tools used for storing data in the DBpedia database. Firstly, citizen clicks on button 'send' to confirm his sending. We use the utility RDFa (Resource Description Framework in attribute) to convert the code of html into RDF. RDFa is a W3C recommendation that allows to add RDF in HTML. Afterwards, we analyse the web page by a RDFa parser to extract the code of RDF. Finally, the RDF graph is stored in the DBpedia database (see Fig. 12).

Therefore, RDFa is an RDF syntax that helps us to integrate directly RDF in HTML attributes. If we take any simple web page, in fact, there are data such as name, email, and status. So, the page can be seen as a document and a data source. Fig. 10 shows an example of a code that presents this integration.

Fig. 10. Integration example.

```
.....
<div foaf=http://xmlns.com/foaf/0.1/
resource="#person" typeof="Person">
<p>
name: <span property="name">Talha
Abid</span>
status: <span property="status">
repairing</span>
mail: <span property="mbox">
abidtalha@gmail.com</span >
</p>
</div>
.....
```

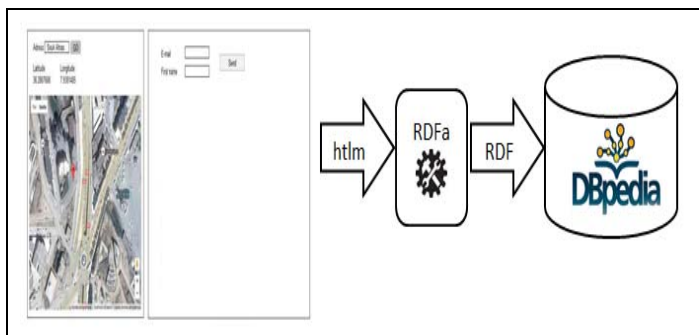
Fig. 11 shows an example of a code written in Turtle format that is obtained from RDFa parser.

Fig. 11. Example of a code written in Turtle format.

```
.....
@prefix foaf:<http://xmlns.com/foaf/0.1/>.
<#person> a foaf:Person;
foaf:mbox "abidtalha@gmail.com";
foaf:name "Talha Abid" ;
foaf:status "repairing" .
.....
```

For the public administrator side, the data are accessible by SPARQL queries through a dedicated Virtuoso [38] triple store. Data are stored in the RDF graphs, and requests can be launched using Sparql to find a new fault in cities.

Fig. 12. Process for converting and storing data in DBpedia.



V. CONCLUSION

Recently, although there have been some changes in a smart cities design with the development of the technology and information, various projects suggest that communication is still ineffective and many problems in the design of the smart cities can be identified. Consequently, it is a common rule that each component of a smart city has its own anatomy, and ontologies are required to provide a certain degree of communication and interoperability across platforms. Thus, in this paper, we have presented a design of a new smart city ontology that focuses on the standard of the semantic Web technologies. The proposed ontology is beneficial for both the citizens and the administrators as it allows interoperability among different systems and frameworks.

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