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Open Data for Italian Municipalities: Ontology, Data and WebApps

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*To my parents
and friends*

Abstract

Sommario

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CSV Comma Separated Values

W3C World Wide Web Consortium

URI Uniform Resource Identifier

HTTP HyperText Transfer Protocol

RDF Resource Description Framework

LOD Linked Open Data

SPARQL SPARQL Protocol and RDF Query Language

IRI International Resource Identifier

ASCII American Standard Code for Information Interchange

1

Introduction

2

Background

2.1 THE WEB OF DATA

The World Wide Web was originally designed to be a space where documents are connected by links without semantic value, and most of these documents are designed for humans to read, not for machines to process. For this reason, Tim Berners-Lee in 2001 introduced the idea of the Semantic Web. In particular, the Semantic Web is an enhancement of the current Web that aims to create a web of data, in which information has a well-defined meaning and can be easily read and processed by programs [BHL01].

Due to this machine-comprehensible capacity, the Semantic Web has enormous potential to automate daily tasks in our lives and is helping to advance scientific and health care fields [Fei+07], such as drug discovery and clinical research, but also in the automotive industry, in the enhancement of cultural heritage, etc. . .¹ In this context, ontologies play a fundamental role in supporting interoperability and common understanding between different web applications and services, solving the problem of semantic heterogeneity [Tay10].

Although there are different definitions of "ontology" [Tay10], in computer science, an ontology is defined as an "explicit and formal specification of a shared conceptualization" [Gru95], where conceptualization means a simplified view of the world we wish to represent. An ontology is made up of four main types of

¹<https://www.w3.org/2001/sw/sweo/public/UseCases/>

2.1. THE WEB OF DATA

components, which are (1) *classes* (or *concepts*), which describe concepts in the domain; (2) *instances* of classes, which represent specific objects or elements of a class; (3) *properties* (or *slots*), which are used to express relationships between a first concept in the domain and a second concept in the range; (4) *axioms* (or *role restrictions*), which are used to impose constraints on the values of instances and classes [Tay10; NM+01]. In addition to the interoperability problem, ontologies are also used to satisfy the following needs:

- To share common understanding of the structure of information among people or software agents;
- To enable reuse of domain knowledge;
- To make domain assumptions explicit;
- To separate domain knowledge from the operational knowledge
- To analyze domain knowledge [NM+01].

Along with ontologies, controlled vocabularies, taxonomies, and thesauri are other resources used in different domains, in particular the medical one [IB14]. A controlled vocabulary is a closed list of named subjects, called *terms*, which is usually used for classification. A taxonomy is a subject-based classification that organizes terms in a controlled vocabulary into a hierarchy. Finally, a thesaurus extends taxonomies, allowing making other statements about the subjects and providing a much richer vocabulary [IB14].

In 2006, Tim Berners-Lee used for the first time the term Linked Data to describe the structured and interlinked data that populate the Semantic Web [Ber06]. He also introduced a set of rules, also known as the Linked Data Principles, to provide some best practices for publishing and connecting data on the Web [BHB11]. These principles, published by W3C, are the following:

1. Use URIs as names for things;
2. Use HTTP URIs so that people can look up those names;
3. When someone looks up URIs, provide useful information, using standards such as RDF and SPARQL;
4. Include links to other URIs so that they can discover more things.

The two main fundamental technologies for Linked Data are Uniform Resource Identifiers (URIs) and HyperText Transfer Protocol (HTTP). In particular, URIs are used to identify any entity that exists in the world, while HTTP provides a simple and universal mechanism for retrieving the resources to which they refer. These two technologies are integrated in RDF, which provides a graph-based data model to structure and link data that describe entities in the world [BHB11]. Using HTTPs, URIs, and RDF, Linked Data builds on the architecture of the Web, called the Web of Data. This means that the Web of Data shares many properties with the traditional Web, which are:

- Web of Data can contain any type of data;
- Anyone can publish data on the Web of Data;
- Publishers are not restricted in the choice of vocabularies used to represent the data;
- Entities are connected by RDF links [BHB11].

However, in addition to those of the traditional Web, the Web of Data also has the following characteristics:

- Data are separated from formatting and presentational aspects;
- Data is self-describing;
- Data access is simplified by the use of the HTTP and RDF standards;
- Web of Data is open, and new data sources can be discovered at run-time by following RDF links [BHB11].

2.2 THE FIVE STARS OF OPEN DATA

Linked Data does not have to be open and can be used internally, such as for personal data. When Linked Data is released under an open license that does not impede its reuse for free, such as Creative Commons CC-BY² or the Italian Open Data License³, we can use the term Linked Open Data (LOD) [Ber06]. In 2010 Tim Berners-Lee developed a star rating system to define and classify Linked Open

²<https://creativecommons.org/>

³<https://www.dati.gov.it/content/italian-open-data-license-v20>

2.3. RDF, OWL, AND SERIALIZATION FORMATS

Data, "in order to encourage people, especially government data owners, along the road to good linked data" [Ber06]. The star rating system assigns a star if the information is publicly available under an open license, even if the information is a photo or an image scan of a table. The more stars the information gets, the easier it will be for people (and machines) to use it [Ber06].

- ★ Available on the Web (any format) but with an open license to be Open Data
- ★★ Available as machine-readable structured data (e.g., Excel instead of an image scan of a table)
- ★★★ Available in a non-proprietary format (e.g., CSV instead of Excel)
- ★★★★ Use URIs to identify things, so that people can point at your stuff
- ★★★★★ Data are linked to other people's data to provide context

However, as the information receives a greater number of stars, both the benefits for consumers and the costs for the publisher increase. In particular, a five-stars data let consumers discover new data of interest, access to the data schema, reuse parts of the data, and link it to other places. They also do not have to pay for tools in order to read the data (e.g., Excel), and they can download and export the data into other formats and process them. On the other hand, to make these data available, publishers must invest time and resources in slicing and organizing the data, assigning URIs to the data items, thinking about how to represent them, linking the data with other data on the Web and making them discoverable [BK11].

2.3 RDF, OWL, AND SERIALIZATION FORMATS

The Resource Description Framework (RDF) is a W3C graph-based standard model to represent information about resources on the Web (including documents, people, physical objects, and abstract concepts). Using RDF, machines can process information on the Web using common parsers and processing tools, and information can be exchanged between different applications without losing meaning [Con+14b]. In particular, in recent years RDF has become the *de-facto* standard for publishing Linked Data on the Web. The core structure of the RDF syntax is a set of

statements, called *triples*, because they consist of three elements: a *subject*, a *predicate*, and an *object*, following the structure <subject> <predicate> <object>, which can be visually represented in Fig. 2.1 [Con+14a].



Figure 2.1: The structure of a triple, with two nodes and a predicate connecting them.

The subject and the object represent the two resources being related. The relationship that goes from the subject to the object is called *property* and its nature is represented by the predicate. A set of statements generate a direct graph, called RDF graph, where subjects and objects are the nodes of the graph, and the predicates form the arcs. For example, the set of triples below produces the graph shown in Fig. 2.2 [Con+14b].

```

<Bob> <is a> <person>.
<Bob> <is a friend of> <Alice>.
<Bob> <is born on> <the 4th of July 1990>.
<Bob> <is interested in> <the Mona Lisa>.
<the Mona Lisa> <was created by> <Leonardo da Vinci>.
<the video 'La Joconde à Washington'> <is about> <the Mona Lisa>
  
```

In an RDF graph, resources may be represented using an International Resource Identifier (IRI), a *literal value* or a *blank node*. An IRI is a generalization of URI, where non-ASCII characters are allowed in the IRI character string. IRIs identify resources, and can appear in all three positions of a triple. In the example above, the IRI for Leonardo Da Vinci in DBpedia⁴ is http://dbpedia.org/resource/Leonardo_da_Vinci.

Literals are basic values such as strings, dates, and numbers. In the RDF graph literals can only be used as objects, and consists of two or three elements, which are: (1) the value itself; (2) an IRI that identifies the *datatype* (string, number, date, etc.); (3) if and only if the datatype is a `rdf:langString`,⁵ a *language tag* (such as `en`, `it`, `fr`, etc.) [Con+14a].

⁴<https://www.dbpedia.org/>

⁵<http://www.w3.org/1999/02/22-rdf-syntax-ns#langString>

2.3. RDF, OWL, AND SERIALIZATION FORMATS

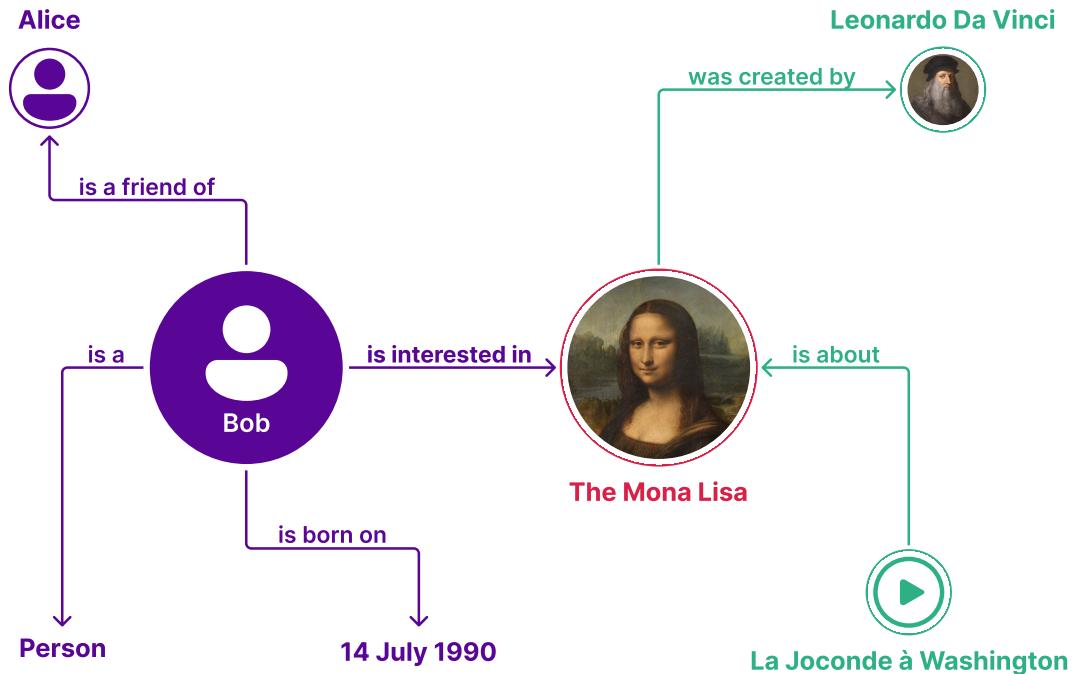


Figure 2.2: The example of the RDF graph presented by W3C.

Finally, blank nodes can appear in the subject and object position of a triple and are used to represent resources without using an IRI [Con+14b].

In Sec. 2.1 ontologies are presented as a core element for creating the Web of Data.

3

State of the Art

4

Analysis

5

Conclusions and Future Works

References

- [Gru95] Thomas R Gruber. "Toward principles for the design of ontologies used for knowledge sharing?" In: *International journal of human-computer studies* 43.5-6 (1995), pp. 907–928.
- [BHL01] Tim Berners-Lee, James Hendler, and Ora Lassila. "The semantic web". In: *Scientific american* 284.5 (2001), pp. 34–43.
- [NM+01] Natalya F Noy, Deborah L McGuinness, et al. *Ontology development 101: A guide to creating your first ontology*. 2001.
- [Ber06] Tim Berners-Lee. "Linked Data - Design Issues". In: (July 2006). URL: <http://www.w3.org/DesignIssues/LinkedData.html>.
- [Fei+07] Lee Feigenbaum et al. "The semantic web in action". In: *Scientific American* 297.6 (2007), pp. 90–97.
- [Tay10] Mohammad Mustafa Taye. "Understanding semantic web and ontologies: Theory and applications". In: *arXiv preprint arXiv:1006.4567* (2010).
- [BK11] Florian Bauer and Martin Kaltenböck. "Linked open data: The essentials". In: *Edition mono/monochrom, Vienna* 710 (2011).
- [BHB11] Christian Bizer, Tom Heath, and Tim Berners-Lee. "Linked data: The story so far". In: *Semantic services, interoperability and web applications: emerging concepts*. IGI global, 2011, pp. 205–227.
- [Con+14a] World Wide Web Consortium et al. *RDF 1.1 Concepts and Abstract Syntax*. Feb. 2014. URL: <https://www.w3.org/TR/rdf11-concepts/>.
- [Con+14b] World Wide Web Consortium et al. "RDF 1.1 Primer". In: (June 2014). URL: <https://www.w3.org/TR/rdf11-primer/>.

REFERENCES

- [IB14] Mirjana Ivanović and Zoran Budimac. "An overview of ontologies and data resources in medical domains". In: *Expert Systems with Applications* 41.11 (2014), pp. 5158–5166.

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