Semantic Web or Web of Data?
A diachronic study (1999 to 2017) of the publications of Tim Berners-Lee and the World Wide Web Consortium

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Abstract

The Web has been, in the last decades, the place where information retrieval achieved its maximum importance, given its ubiquity and the sheer volume of information. However, its exponential growth made the retrieval task increasingly hard, relying its effectiveness on idiosyncratic and somewhat biased ranking algorithms. To deal with this problem, a "new" Web, called Semantic Web (SW) was proposed, bringing along concepts like "Web of Data" and "Linked Data", although the definitions and connections among these concepts are often unclear. Based on a qualitative approach built over a literature review, a definition of SW is presented, discussing the related concepts sometimes used as synonyms. It concludes that the SW is a comprehensive and ambitious construct that includes the great purpose of making the Web a global database. It also follows the specifications developed and/or associated with its operationalization and the necessary procedures for the connection of data in an open format on the Web. The goals of this comprehensive SW are the union of two outcomes still tenuously connected: the virtually unlimited possibility of connections between data - the web domain - with the potentiality of the automated inference of "intelligent" systems - the semantic component.

Keywords: Semantic Web, Web of Data, Linked Data, Linked Open Data, Tim Berners-Lee; World Wide Web Consortium, LOD, W3C

Introduction

We have seen in the last decades an exponential increase of the information produced in the context of the World Wide Web (WWW), also called "the web" or simply "web". In this informational transition, from analogue to digital, information systems and its users demanded more efficient information retrieval tools and techniques, in terms of both precision and recall (Patel-Schneider & Horrocks, 2007; Souza & Alvarenga, 2004, p. 133). Big companies like Google, Apple and Microsoft have offered search engines with their own advanced and idiosyncratic ranking algorithms, deepening the information bubbles and exacerbating the information silos. In this context, we would expect that the tools available in the digital environment could evolve in order to offer more efficient management of resources and better information retrieval. A "new" Web, called the *Semantic Web*, was presented as one possible solution to this situation. The Semantic Web (SW), although late implementation, was the original proposal for the web (Berners-Lee, 1990; Berners-Lee, 1998; Bizer, Heath & Berners-Lee, 2009) and have been designed and deployed for almost 20 years, in parallel with the web as we know. One of SW's expectations is to enable an environment where agents, a specific type of "intelligent" software, can perform complex tasks according to the users' needs

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(Berners-Lee, 2006; Berners-Lee & Fischetti, 2000, p. 237; Berners-Lee, Hendler, & Lassila, 2001). The big question that arises in this scenario is the need to make the machines capable of reasoning similar to that of humans, resulting in an association with the so-called Artificial Intelligence, which the makers of the SW, since the first papers, sought to exclude (Berners-Lee & Hendler, 2001, p. 1023).

Although the idea of making human knowledge available and ready to be used to foster collaborative work were at the basis of the development of the WWW (Berners-Lee, 2009, 2:40), this same idea was foreseen and developed by Paul Otlet, the founder of the Universal Decimal Classification, half a century before the Berners-Lee digital web (van den Heuvel, 2009; van den Heuvel & Rayward, 2011, pp. 9–10). However, the current WWW is the most important scenarium where information is sought, in terms of volume and ubiquity. In this context, the potential of a semantic web, with regard to the aid it could provide in the retrieval of information online seems essential

Nevertheless, the concept of Semantic Web is ambiguous and misinterpreting, given its biasing connection with the term "semantics" (Almeida, Souza, & Fonseca, 2011; Setzer, 2015) and the association to other terms such as *Web of Data*, *Linked Data* or even *Web of Linked Data*. We, unlike authors such as Feigenbaum (2011) consider that there are differences, both intrinsic and contextual, between the terms: Semantic Web; Web of Data; Linked Data and Web of Linked Data, that justify a conceptual demarcation and proper clarification. In this context, this paper intends to dig deeper into the definitions and concepts related to the Semantic Web, in order to clarify and distinguish it from the concept of Web of Data. We understand that, while avoiding a pompous and unnecessary digression, some exegesis on ambiguous terms and definitions belonging to areas of knowledge that are not yet well established are part of the motivations of researchers in this area, insofar as they provide clarity and promote the alignment between the conceptual, pragmatic and technological aspects of the field. Each one of the four terms being analyzed have been regarded as (almost) independent research and development areas for themselves, yet its intersections are fuzzy and getting fuzzier.

The conceptual analysis of the term Semantic Web proposed in this study aims to contribute to a better understanding of it, in particular by researchers from areas not directly related to this topic (Ali Shiri, 2015). We believe that any communication that is intended to be clear and objective needs a conceptual clarification, especially in an interdisciplinary field (Delattre, 1981, p. 23; Kuhn, 1996, p. 200). In this context, it is worth to adopt a diachronic perspective, aiming at clarifying the concept of SW. We start the analysis using the definitions adopted by its creator, Sir Timothy Berners-Lee (Berners-Lee, 1998; Berners-Lee & Fischetti, 2000, p 177) and then evolved to find subsidies for the understanding of the intricate relationship of the several concepts involved (Cambridge Semantics, 2016; Heath, 2009). It is not, however, our intention to present a "closed" or final judgment, given the semantic openness and operational vagueness inherent to any definition and conceptual categorization, which does not invalidate its crucial importance in the construction of knowledge (van de Ven, 2013, p.116).

Methodology

We have chosen a qualitative approach based on a literature review using the research method known as content analysis (Bardin, 2011; Kuckartz, 2014). The analysis focused on the conceptual evolution, as we have observed the changes in definitions over time (Hampton, 2016, p. 662), starting from a set of documents selected by Berners-Lee himself (Berners-Lee, 2018), and a set of W3C´s web pages about the SW (see Table 1). The inclusion of the references associated with the W3C was considered relevant as the main and official source regarding WWW issues.

Table 1

Documentary references used in the conceptual analysis of the Semantic Web

Ref.	Date	Author(s)	Document	Context
SP.01	1999 Jun.7	Berners-Lee, Connolly, Swick	*Web Architecture: Describing and Exchanging Data*	*W3C Note*
SP.02	1999 Sep.22	Berners-Lee, Fischetti	*Weaving the Web*	Book
SP.03	2001 Apr.26	Berners-Lee, Hendler	*Publishing on the Semantic Web*	*Nature* (article)
SP.04	2001 May	Berners-Lee, Hendler, Lassila	*The Semantic Web*	*Scientific American* (article)
SP.05	2002 Oct.	Hendler, Berners-Lee, Miller	*Integrating Applications on the Semantic Web*	*The Journal of The Institute of Electrical Engineers of Japan* (article)
SP.06	2005 Sep.13	Berners-Lee, Hall, Hendler, Shadbolt, Weitzner	*The Emerging Science of the Web*	*Web Science Workshop* (report)
SP.07	2006 Jun.	Shadbolt, Hall, Berners-Lee	*The Semantic Web Revisited*	*IEEE Intelligent Systems Journal* (article)
SP.08	2006 Aug.11	Berners-Lee, Hall, Hendler, Shadbolt, Weitzner	*Creating a Science of the Web*	*Science* (article)
SP.09	2006 Sep.	Berners-Lee, Hall, Hendler, O'Hara, Shadbolt, Weitzner	*A Framework for Web Science*	*Foundations and Trends in Web Science* (article)
SP.10	2008 Oct.	Shadbolt, Berners-Lee	*Web Science: Studying the Internet to Protect Our Future*	*Scientific American* (article)
SP.11	2009 Mar.	Bizer, Heath, Berners-Lee	*Linked data - The story so far*	*International Journal on Semantic Web and Information Systems* (article)
W3.01	2009 Jun.18	Berners-Lee	*Linked data*	*W3C Design Issues for Word Wide Web*
W3.02	2009 Oct.22	Berners-Lee	*Web 2.0 Summit 09 discussion: Conversation with Tim Berners-Lee*	*W3C Semantic Web Activity: Publications / Articles / Interviews*
W3.03	2009 Nov.12	W3C	*W3C Semantic Web*	*W3C Semantic Web: Frequently Asked Question*
W3.04	2013 Jun.27	W3C	*SemanticWeb*	*W3C Wiki*
W3.05	2013 Dec.11	W3C	*W3C Semantic Web Activity*	*W3C SW Activity* (introduction and *What is the Semantic Web?*)
W3.06	2015	W3C	*Semantic Web*	*W3C Standards* (introduction and *Linked Data*)
W3.07	2017 Oct.11	W3C	*Semantic Web Wiki*	*SW Wiki* (*Main Page*)
W3.08	2017	W3C	*W3C Data Activity: Building the Web of Data*	*W3C Data Activity* (*Context & Vision*)

Note: SP - references included in the “Selected Publications” section of Berners-Lee's biography; W3 - references extracted from the pages of the W3C website devoted to the Semantic Web.

Despite the fact that the earliest reference of the “Selected Publications” dates back from 1999, it is important to mention that earlier, at the first World Wide Web Conference in 1994, Berners-Lee explicitly exposes, for the first time, the question of web semantics (Berners-Lee, 1994; Shadbolt, Hall, Berners-Lee, 2006, p.96). It is, however, after 1998 that the term Semantic Web begins to be referred more often in scientific papers.

The corpus was subjected to a comparative analysis based on three categories: i) the descriptive characteristics, ii) the structural basis and iii) the goals and functionalities. These categories correspond to the following questions: i) what can be understood by Semantic Web, ii) what is necessary to make the Semantic Web a reality and iii) what are the goals of the Semantic Web?

During the pre-analysis of the documents a hypothesis was constructed, according to which the concept of the Semantic Web would have evolved over time, in order to follow the current trends and adapt to the technological and informational constructs that have derived from the original ideas and framework. This idea is supported by Marcondes (2012, p. 26), that says that there is a "significant change from the original proposal" from a "web of meanings" to a "data web", regarding W3C's "much more realistic view" presented by W3C in 2010.

The first phase of our analysis corresponded to the systematization of the recording units (Bardin, 2011, p. 134; Kuckartz, 2014, p. 44), according to the three categories considered (i.e. the descriptive characteristics, the structural basis, and the goals/functionalities), based on which the analysis was carried out. In a second phase, a categorization by corpus (Bardin, 2011, p. 149) was carried out, leading to the constitution of the groups and the definition of their respective conceptual titles, all done after the analysis of the recording units considered in each category. Further, as a visual aid, a temporal analysis (Yin, 2014, pp. 150–152) was chosen for the correct understanding on how those units deployed with time. The methodology applied implied building analytical-theoretical categories (Kuckartz, 2014, p. 41), systematized in Figure 1.

Survey questions	Content analysis		Time-series analysis (1999-2017)
	first phase	second phase	
	analytical-theoretical categories		
What can be understood by Semantic Web?	i) The descriptive characteristics	Web of Data (1a)	(i) Explicit references
			(ii) Implicit references
			(iii) Reference as part of Web of Data
		Linked Data (1b)	(i) Explicit references
			(ii) Implicit references
			(iii) Reference as a means to reach the Web of Data
		Descriptions that include "semantics" (1c)	(i) Web of Understanding/Knowledge
			(ii) Web of Logic/Information with meaning
			(iii) Web of Data with meaning
What is necessary to make the Semantic Web a reality?	ii) The structural basis	Procedures (2a)	(i) Procedures related to the structuring of data for automatic processing
			(ii) Procedures focused on creating interoperability between systems and data link
			(iii) Descriptions that presented the two typologies established
		Architecture (2b)	(i) Concepts/Abstractions
			(ii) Specifications/Standards
what are the goals of the Semantic Web?	iii) Goals and functionalities	Using the Web as a global database	
		Automatic processing of semantics by "intelligent agents"	
		Interconnection of several databases in the Web	

Figure 1. Systematization of the analytical-theoretical categories used for the qualitative analysis of the corpus.

Results

Based on the selected corpus (see Table 1) we present the concept of Semantic Web according to the categories determined a priori: i) the descriptive characteristics, ii) the structural basis and iii) the goals and functionalities.

Descriptive characteristics

In the Descriptive Characteristics category, the recording units were organized into three groups: Web of Data (1a), Linked Data (1b) and descriptions that include "semantics" (1c). The names of groups 1a and 1b are derived from the relationship with the concepts expressed in the respective recording units. In group 1c, the designations resulted from the relation between the concepts: semantics, logic, understanding and knowledge (Almeida et al., 2011), also expressed in the recording units included in this group. Within the groups, additional distinctions were made, as we can see in Table 2.

Table 2
Groups and respective recording units considered in the analysis category 1- Descriptive characteristics

Groups		Recording units and correlated references from table 1
(1a) Web of Data	i.	A Web of Data (SP.11, W3.03, W3.04, W3.05, W3.06, W3.07);
	ii.	One extension of the Web moving from text documents to data resources (SP.08); Is intended to function in the context of the relational model of data (SP.09);
	iii.	Part of the Web of Data (W3.08).
(1b) Linked Data	i.	The Web of linked data (W3.06, W3.07).
	ii.	A new data model to support the linking of data from many different models (SP.01); The web of connections between different forms of data (SP.02); A world of trusted information shared along collaborating groups of users (SP.03); An open web of inter-referring resources (SP.08); A type of extension of the Web to extend the Web to cover linked data (SP.09); A network of data on the Web (SP.10); The Semantic Web isn't just about putting data on the web. It is about making links (W3.01); The world of linked data (W3.02).
	iii.	Linked Data provides the means (SP.11); Linked data is essential to actually connect the semantic web (W3.01).
(1c) descriptions that include "semantics"	i.	The Web of understanding (SP.01); A universal web of knowledge (SP.03);
	ii.	An extension of the current Web in which information is given well-defined meaning (SP.04, SP.05); A web of logic (SP.06); A Web of actionable information derived from data through a semantic theory for interpreting the symbols (SP.07);
	iii.	A web of data with meaning (SP.02).

Note: In the references inserted in the item iii of the group 1b, the term "Linked Data" does not appear as a description for the Semantic Web. However, its inclusion was considered relevant since the term is later used as a definition by the W3C.

This categorization highlights three possible definitions for what can be understood by Semantic Web. The first two, group (1a) and group (1b), respectively identify SW as a Web of Data and, more specifically, a Web of Linked Data. The definition (1c), encompassing the original term "semantics", stands out from the previous groups by its difficulty in having assigned an identifiable label. With respect to the hypothesis formulated on the evolution of the SW concept, meaning it was directed towards a more concrete and immediate operationalization, the analysis of how the different "descriptions" articulate over time points to the confirmation of the same (see Figure 2). As an evidence of this evolution, one can enumerate:

i. The descriptions of group 1c, which present a greater degree of complexity - given the use of terms such as understanding, knowledge, meaning or logic, are found in documents dated from the first half of the analyzed period (1999 to 2006);

ii. The concentration of explicit references to the concepts of Web of Data and Linked Data is observed in the most recent documents (after 2009);

iii. In the documents dated to 2015 and 2017 (ref. W3.06 and W3.07), the specification of the term Semantic Web appears restricting its scope: "The term 'Semantic Web' refers to W3C's vision of the Web of Linked Data." (W3C, 2015b, 2017a);

iv. The integration of Semantic Web Activities in W3C Data Activity whose goal is the construction of Data Web (W3C, 2017b).

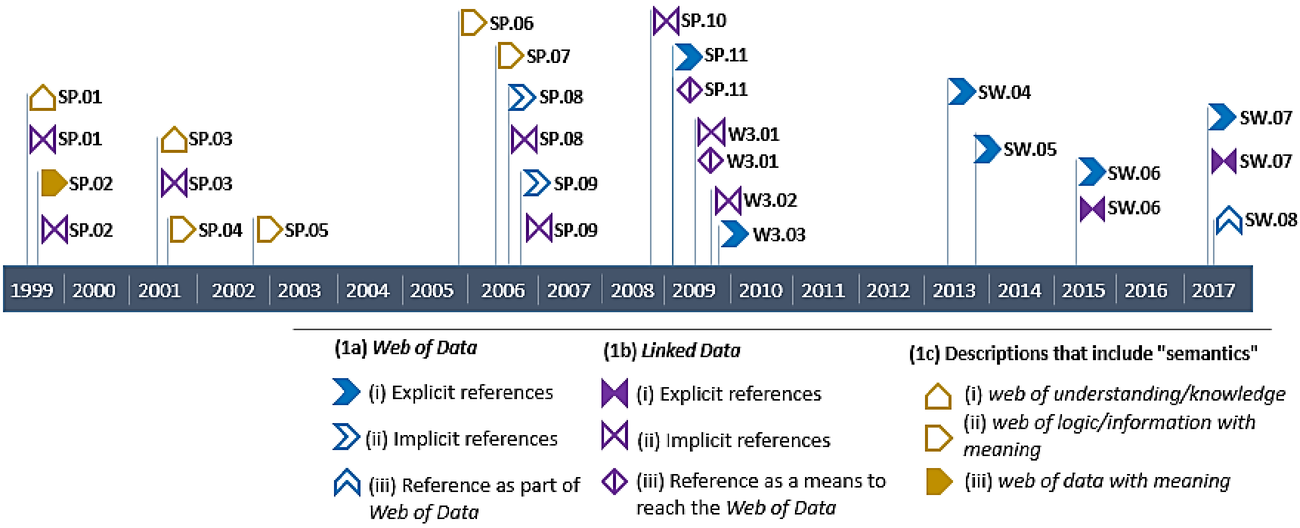

Figure 2. Temporal distribution of the recording units of Descriptive Characteristics category, (source: the authors).

It is necessary to highlight, in regard to these considerations, that a description of SW explicitly mentions the concept of Web of Data prior to 2009 in the book *Weaving the Web* (ref. SP.03 of Table 1). However, this reference has been included in the group (1d) descriptions that include "semantics," given the description contained in the glossary of that document: "Semantic Web: The Web of Data with meaning in the sense that a computer program can learn enough about what the data means to process it." (Berners Lee & Fischetti, 2000, p. 237). Likewise, it is interesting to check the evolution of the Linked Data concept. In 2009 Linked Data is considered a mean to reach the Semantic Web: "while the Semantic Web, or Web of Data, is the goal or the end result of this process, Linked Data provides the means to reach that goal." (Bizer et al., 2009, p. 17). Conversely, in 2013 and 2015, in account of the vision of the W3C, as explained in point iii., this appears to be the Semantic Web itself. This interpretation causes some perplexity since the same document of 2015 (ref. W3.06) presents this description accompanied by another one that clearly states: "The Semantic Web is a Web of Data." (W3C, 2015b).

Although this is not a single case of disparate descriptions in the same document (as can be seen in Table 2 and Figure 2), it seems to indicate that the three terms, (Semantic Web, Web of Data and Linked Data) refer to the same concept. This interpretation is contrary to what is presented in the previous references regarding those concepts, because the scope of SW is exposed as more comprehensive than that of Linked Data. Another possibility is that the terms Linked Data and Web of Linked Data represent concepts with different contexts; the latter being equivalent to the concept of Web of Data that emerges as a more concrete definition for SW replacing the term semantic with data. Although this last interpretation presents a possible explanation for the apparent mismatch, a more realistic explanation would be considering a semantic drift for different authors, views and interpretations. In spite of this, it is possible to verify, on the basis of this domain of analysis, a turning point from the abstract "semantic", associated with the "understanding" (the Semantic Web), for the "syntactic" processing using Linked Data (the Web of Linked Data), more properly associated to the computational methods.

Structural basis

In this category of analysis, the recording units adopted were:

a. Descriptions of procedures;
b. Descriptions of concepts/abstractions/specifications/standards that are, directly or contextually, presented as necessary or even essential for the development of W3.

The descriptions of procedures were inserted into group with the same label, Procedures (2a). Analyzing the recording units of this group, a pattern was identified in the descriptions and it is possible to distribute them into three subgroups: i) procedures related to the structuring of data for automatic processing, ii) procedures focused on creating interoperability between systems and data link and iii) descriptions that presented the two typologies established (see Table 3).

Table 3
Group 2a (Procedures) and respective recording units

Recording units and references from table 1
Group 2a: Procedures
i. describing explicit relationships between things and containing semantic information intended for **automated processing** (SP.01); The first step is putting data on the Web in a form that **machines can naturally understand**, or converting it to that form (SP.02); More information needs to be in a form that the **machine can "understand"** rather than simply display (SP.03);
ii. requires increasing the amount of **data exposed in RDF** (SP.07); Linking is key to the SW…. in many cases the practice has been the **conversion of data into RDF** (SP.09); with **Linked Data** as a foundation (SP.11); put the data out there and **using standards URIs to things and make links** (W3.02); requires a focus not just on the **interoperability** of data but of communities (W3.08);
iii. It is based on the idea of having **data on the Web defined and linked** (SP.06); creation of a common framework that **allows data to be shared** and reused **across application**, enterprise, and community boundaries, **to be processed automatically** by tools as well as manually (W3.03); It is about **common formats for integration and combination of data** drawn from diverse sources.... It is also about language for recording **how the data relates to real world objects** (W3.05).

Note: The emphasis in bold corresponds to the segment with the greatest weight in the categorization of the respective recording units.

Descriptions of concepts/abstractions/specifications/standards were included in a second group entitled Architecture (2b). In this group, recording units were naturally associated with one of the two subgroups that constitute it: i) concepts/abstractions or ii) specifications/standards (see Table 4).

Table 4 (continued)
Group 2b (Architecture) and respective registration units

Recording units and references from table 1
Group 2b: Architecture
i. The Semantic Web must be based on a **facility that can expand** as human understanding expands (SP.01); the third basic component of the Semantic Web [is] collections of information called **ontologies** (SP.04); **Logic and ontologies** will suffice to extract much of the value from the data held in structured relational databases (SP.06); information derived from data through a **semantic theory** for interpreting the symbols (SP.07); the "Semantic Web" of **relational data and logical assertions**, computer logic is in its element (SP.08); The Semantic Web is characterized by the use of **Graphs and Networked Data** (W3.03);

Note: The emphasis in bold corresponds to the concepts/abstractions and the identified specifications/standards.

Table 4 (continued)
Group 2b (Architecture) and respective registration units

Recording units and references from table 1
Group 2b: Architecture
ii. Layers of the semantic web are built as new languages and tools anchored in **XML** (SP.03); Two important technologies…. are already in place: **XML and RDF** (SP.04); a fundamental component of the Semantic Web is the **RDF**; **URIs** is still the critical architecture (SP.06); The Semantic Web can't exist without carefully developed and agreed standards [like **RDF**] (SP.07); the primary language—the **RDF**…. The subjects, verbs and objects are each identified by a **URI** (SP.10); Use **URIs** as names for things; When someone looks up a URI, provide useful information, using the standards (**RDF***, **SPARQL**) (W3.01); **RDF**, which is one of the fundamental building blocks of the Semantic Web, plays the role of a common model (W3.03); what is called "Big-S Semantic Web"-data formats such as **RDF and OWL** (W3.04); It is based on the **RDF** (W3.05); Linked data are empowered by technologies such as **RDF, SPARQL, OWL, and SKOS**…. **RDF** provides the foundation for publishing and linking your data. Various technologies allow you to embed data in documents (**RDFa, GRDDL**) or expose what you have in SQL databases (W3.06); Linked data are empowered by technologies such as **RDF, SPARQL, JSON-LD, OWL, and SKOS** (W3.07).

Note: The emphasis in bold corresponds to the concepts/abstractions and the identified specifications/standards.

By observing the elements indicated in the timeline (Figure 3), according to the dates of the respective documents, there is a concentration of the procedures focused on the creation of interoperability between systems and in the connection of data (group 2a ii.) from 2006 on, disregarding those exclusively related to the structuring of data for automatic processing (group 2a i., see Figure 3).

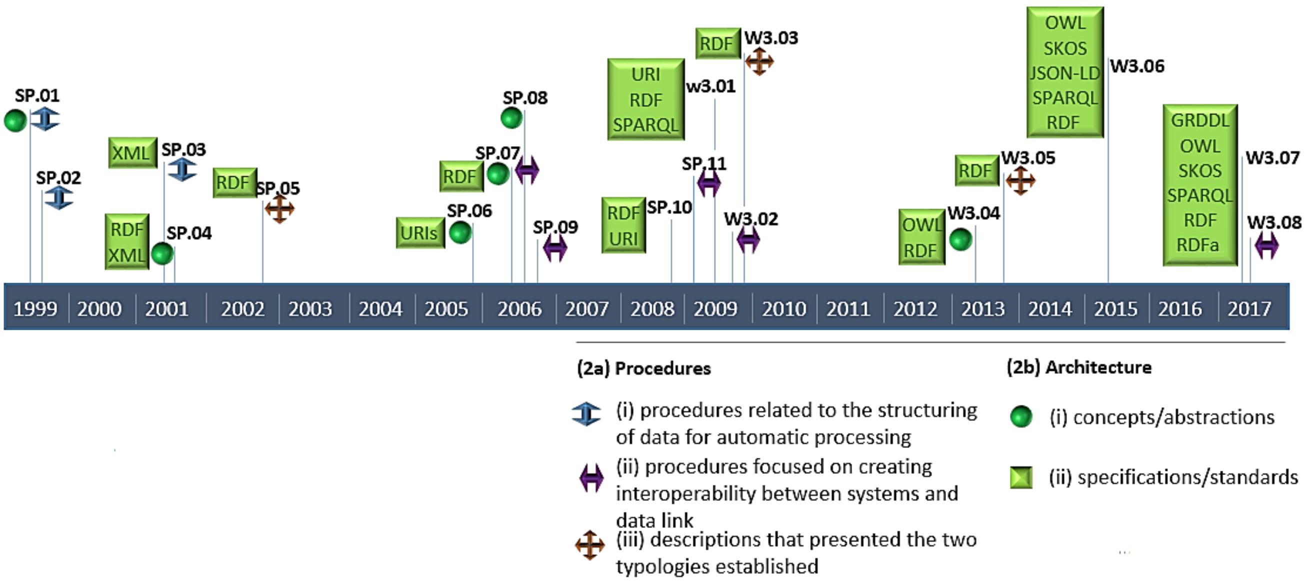

Figure 3: Temporal distribution of the recording units of Structural Basis category, (source: the authors).

This is a strong support for the conceptual drift in term the Web of Linked Data. In the most recent references of group (2b), we can observe the presence of the concept of Web of Linked Data. This presence is noted both at the level of concepts/abstractions, with the use of an alternative term for the Linked Data: Networked Data (ref. W3.03), as well as in the specifications associated with this concept: "Linked data are empowered by technologies such as", present in the references W3.06 and W3.07 (see Table 5). It can be observed that these two references are of the most recent, with the greatest amount of specifications/standards present in these descriptions, being six in ref. W3.06 and five in ref. W3.07. This may be related to the time required for the development and maturation of the specifications; however, the direct relationship established in these two documents, between specifications and the term Linked Data, can be interpreted as a way to operationalize SW by reducing its scope.

Goals and functionalities

From the descriptions of the goals and functionalities of the SW project, constituents of the recording units, it was possible to verify the presence of a recurring operational purpose: "to use the Web like a single global database" (Bizer et al., 2009), a concept that, assuming different expressions, can be identified in seven of the seventeen references (see table 5).

Table 5
Recording units that point to SW's general objective of using the Web as a global database

Year	Recording units and references from table 1
1999	to support the linking of data from many different models (SP.01)
2002	[for] linking of databases (SP.05)
2005	to exploit the large amount of data in structured relational databases (SP.06)
2006	to allow independent consistent data systems to be connected locally without requiring global consistency (SP.08)
2009	to use the Web like a single global database (SP.11); [to do] data oriented queries (W3.02)
2013	[to] allows a person, or a machine, to start off in one database and then move through an unending set of databases which are connected not by wires, but by being about the same thing (W3.05)
2015 and 2017	to build a technology stack to support a "Web of data," the sort of data you find in databases (W3.06, W3.07)
2017	to lead the use of the Web as an exchange medium for data as well as documents (W3.08)

Note: The year presented corresponds to the date of the source document.

There is also an explicit reference to the idea of the "global database" in the 2015 document (ref. SW.06), regarding the need for the SPARQL (Protocol and RDF Query Language), query language for the Semantic Web, coherent with the vision of a global database (W3C, 2015b). In the references of 2013 and 2015 (SW.05 and SW.06), the purpose of SW is expressed in a less precise way (W3C, 2013b, 2015b). A possible interpretation for this type of discourse may be linked to a more cautious approach to the complexity of the idea of the global database. The mention to expressions such as "most useful work done by computers" and "reliable network interactions", being quite generic, does not show commitment to specific objectives that are potentially hard in terms of their realization in the short or medium term (Codina, 2003, p. 151; Ray, 2010, 7:00). Dubious goals like these are found in some of the functions expected for SW expressed in the documents up to 2009 (see table 6).

Table 6 (continued)
Recording units that point to expected functions of the SW related to automatic processing and/or intended for the "end users" of the computational system

Year	Recording units and references from table 1
1999	to capture information that links independent representations of overlapping areas of knowledge (SP.01)
1999	[to] learn enough about what the data means to process it.… to do something [with the data] it wasn't able to do directly (SP.02)
2001	[for] new and better search engines, and users will thus be able to issue significantly more precise queries.… [for] automated methods for helping users to understand the content produced by those in other scientific disciplines (SP.03)
2001	[to] bring structure to the meaningful content of Web pages, creating an environment where software agents roaming from page to page can readily carry out sophisticated tasks for users (SP.04)

Note: "End-user" means the user who only uses the fully developed and finalized system, using it for the purpose for which it was designed.

Table 6 (continued)
Recording units that point to expected functions of the SW related to automatic processing and/or intended for the "end users" of the computational system

Year	Recording units and references from table 1
2008	to give much more targeted answers to our questions…. a person will instead receive detailed information (SP.10)
2009	in resource discovery and classification to provide better, domain specific search engine capabilities;…. by intelligent software agents to facilitate knowledge sharing and exchange; in content rating (W3.03)

Note: "End-user" means the user who only uses the fully developed and finalized system, using it for the purpose for which it was designed.

Confronting the three categories, the latter seems to contradict a more concrete and restricted operationalization, as pointed out by the other two. However, if we interpret this change as a way to avoid potentially more remote goals, this does not entirely contradict the hypothesis formulated that points to *an operationalization, of the concept of SW, more concrete and immediate*. Regarding the concrete operationalization of the project for the web, the point is to define the functionalities offered by the SW. If SW functions are not restricted to end users, as defined in the note in Table 6, we may also consider the following specific procedures, expressed in document W3.06 (W3C, 2015b):

i. publish and link data using the RDF format;
ii. use "technologies" such as RDFa or GRDDL to insert data into documents, expose the contents of an SQL database, or make them available in RDF format.

This type of functionalities (i, ii) can also be seen in other previously published documents (SP.05), where they are mentioned as functions performed in 2002 by Semantic Web technologies (Hendler, Berners-Lee, & Miller, 2002), as follows:

i. the connection between databases;
ii. Sharing content between applications using different XML DTDs or other Schemas;
iii. The discovery and combination of web services.

Despite the distance separating the two documents (2002 and 2015), the difference between these two "sets" of functions lies in the specifications described, since their purpose is the same - to interconnect several databases in the Web (W3C, 2015a).

Discussion

The analysis confirms the hypothesis formulated initially: the concept of the Semantic Web has undergone an evolution over time, in order to make its operation more concrete and immediate. However, the Semantic Web concept itself was unclear, as already noted by Almeida et al. (2011). One can perceive the confusing conceptual relationship with the terms Web of Data and Linked Data in the scope of the three domains analyzed, and it is clear the change in the terminological and conceptual use from Semantic Web for Web of Linked Data or simply for Linked Data and, in parallel, the use of Web of Data for the same concept.

Semantic Web, Web of Data, Linked Data: possible definitions

Even though a document issued in 2015 (W3.06 of Table 1) points to a synonymy between the three concepts, other references obscure this relationship or even contradict it. As an example, the current web page on Linked Data of W3C depicts the relations between the three concepts in a somewhat contradictory way. The fact that the example used in Table 7 is from a nested web page, accessed from the page where it is expressed that the term Semantic Web refers to the W3C view of the Web of Linked Data (W3C, 2015b) makes the relations between the three concepts even more complex, contradicting the inference d. of the same Table. However, the "taxonomy" used on the W3C website for the organization of the referred pages (see note in Table 7) confirms this same inference by placing the page about Linked Data hierarchically subordinated to the page about Semantic Web.

Table 7
Example of the contradictory relations of synonymy and hierarchy between the Semantic Web, Web of Data and Linked Data concepts based on the same source

Excerpts of the text[a]	Inferences
A. *The Semantic Web is a Web of Data*	a. Semantic Web and Web of Data are different terms for the same concept.
B. *to make the Web of Data a reality, it is important to have the huge amount of data on the Web available in a standard format, reachable and manageable by Semantic Web tools*	b. If the Semantic Web encompasses the tools to achieve the Web of Data, there is no sense in treating both as the same concept.
C. *relationships among data should be made available to create a Web of Data. This collection of interrelated datasets on the Web can also be referred to as Linked Data*	c. Web of Data and Linked Data can be described as a collection of web-based interconnected databases, what configures a synonymy relationship between the concepts.
D. *Linked Data lies at the heart of what Semantic Web is all about: large scale integration of, and reasoning on, data on the Web*	d. Linked Data is at the heart of Semantic Web, so it will be the most important part, but not the whole

Note: The page entitled *Linked Data* is in the W3C website under the following hierarchy: *W3C* - *Standards* - *Semantic Web* - *Data* (https://www.w3.org/standards/semanticweb/data).
[a] Excerpts retrieved from the sections: "What is Linked Data?" and "What is Linked Data Used For?".

Given this inter-relational complexity of the three concepts, we deem necessary to present a clear definition for the concept of Semantic Web and its relationship with the other two terms, Web of Data and Linked Data. Semantic Web refers to comprehensive construct that includes:

i. the great purpose of making the Web a global database, including the applications/interfaces necessary for its use;
ii. the specifications (standards, languages, vocabularies, protocols) developed and/or associated with their operation;
iii. the principles and respective procedures associated with the practice of open data linking on the web, as a basis for the whole concept.

By Web of Data we extend the World Wide Web adding the Semantic Web in this new environment, where it is possible to perform queries similar to those made in databases, regardless of the type, format and source of that data, and having, as a result, semantically interrelated data, that is, information, instead of simple documents, often without semantic link between them, as in the current "Web of documents" (W3C, 2013b, 2015b).

The Web of Data is thus directly related to point (i.) referred to in the Semantic Web definition; given the fact that the term Web of Data is used more frequently when the SW objective is mentioned (Berners-Lee, 1998; Bizer et al., 2009; Hendler et al., 2002; W3C, 2017b). On the other hand, when there are references to "tools", "technologies" or something similar to what is exposed in point (ii.), the term Semantic Web is used instead of Web of Data (Berners-Lee et al., 2006, p. 108; Hendler, Shadbolt, Hall, Berners-Lee, & Weitzner, 2008, p. 68; W3C, 2015b, 2017a)

Finally, the concept of Linked Data is understood as a set of procedures and rules for the publication of data on the Web in order to allow the connection of the data to other data from different sources (Bizer et al., 2009). Although the term Linked Data can also be associated with data binding outside the Web environment when we see a mention to "Semantic Web technologies", the great value of this set of procedures, rules and associated specifications is the adaptation of the Web (W3C, 2017b).

The concept of Linked Data is thus associated with that explained in section (iii.) regarding the SW definition–principles and procedures associated with the practice of open data linking on the web. In this context, the introduction of the concept of Linked Open Data makes perfect sense given the "principle of universality" and the open standards that characterize the WWW: "The principle of universality allows the Web to work no matter what hardware, software, network connection or language you use and to handle information of all types and qualities. (Berners-Lee, 2010, p. 82).

The link between the terms Web of Data and Linked Data, and the concepts presented, respectively, in (i.) –making the web a global database, and (iii.) –principles and procedures for linking data on the web, as well as the association between the term Semantic Web technologies and that referred to in (ii.) –specifications associated with the SW objectives, can still be found simultaneously in excerpts from documents such as those exemplified by:

> Semantic web technologies [ii.] and Linked Data principles [iii.] are paving the way for the Web of Data, a global data space [i.] that relies on a stack of technologies like URIs, HTTP, and RDF to empower information retrieval. (Parreiras, 2012, p. 189).
>
> In the context of the emergent Web of Data [i.], a large number of organizations, institutes and companies (e.g., DBpedia, Geonames, PubMed ACM, IEEE, NASA, BBC) adopt the Linked Data practices [iii.] and publish their data utilizing Semantic Web technologies [ii.]. (Bikakis, Tsinaraki, Gioldasis, Stavrakantonakis, & Christodoulakis, 2013, p. 2).

From the Web of Linked Data to the Web of Data

To further clarify the matter, it is critical to address the concept of Web of Linked Data. Early in this study, it was mentioned the possibility of the terms Linked Data and Web of Linked Data being representing concepts with different coverage; the former covering a lesser extent than the latter, and this latter being a quasi-synonym of the concept of Web of Data, specifying the data type "of this Web". According to this, and in the scope of the three concepts (Semantic Web, Web of Data and Linked Data), a more restricted understanding of the concept "Web of Linked Data" is made when associated with the term "Web of Data".

According to this narrower view, it can be noted in a W3C tutorial of 2014 that, by Web of Linked Data within the Semantic Web Standard Stack, only the SPARQL and RDF specifications are considered. These specifications relate, respectively, to the components: query and representation (see Figure 4). Web of Data, as presented in the previous point, requires the reasoning component or, putting in another way, it needs a set of rules, for automatic data processing, its consistent integration and the discovery of new relations between them, in a process called inference.

A similar perspective can be found in the isometric projection of the "Semantic Web technology stack", where only a small fraction of the technologies is considered to belong to the Linked Data stack (see Figure 5). This representation is an adaptation made by Parapontis (2012) to the original picture by Nowack; a change that reinforces what was shown above about the components included in the Web of Linked Data. The original representation does not describe the "technologies" that are part of the Linked Data stack and excludes the Query layer. The inclusion of this layer and the indirect linking to the formats and models layers happened in 2012, as can be seen in the Figure 5. It presents the specifications SPARQL, RDF and URI/IRI as the "Linked Data stack technologies", that is, including only the query and representation layers.

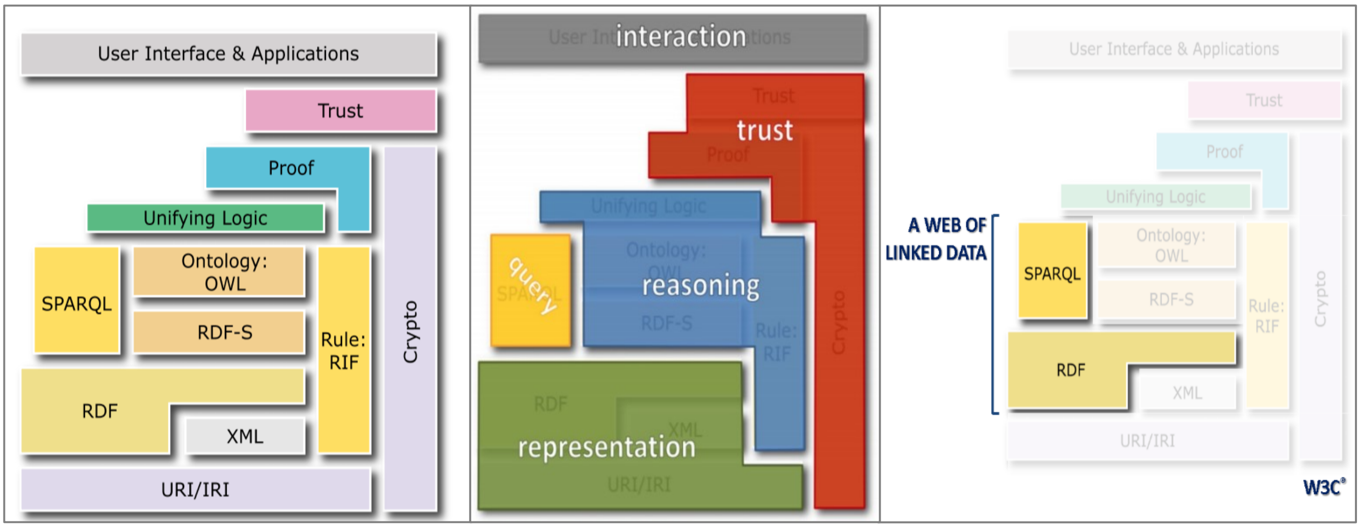

Figure 4. Three slides from the Linked Data tutorial presented at the 23rd International World Wide Web Conference in April 2014 by Fabien Gandon, (CC-BY license).

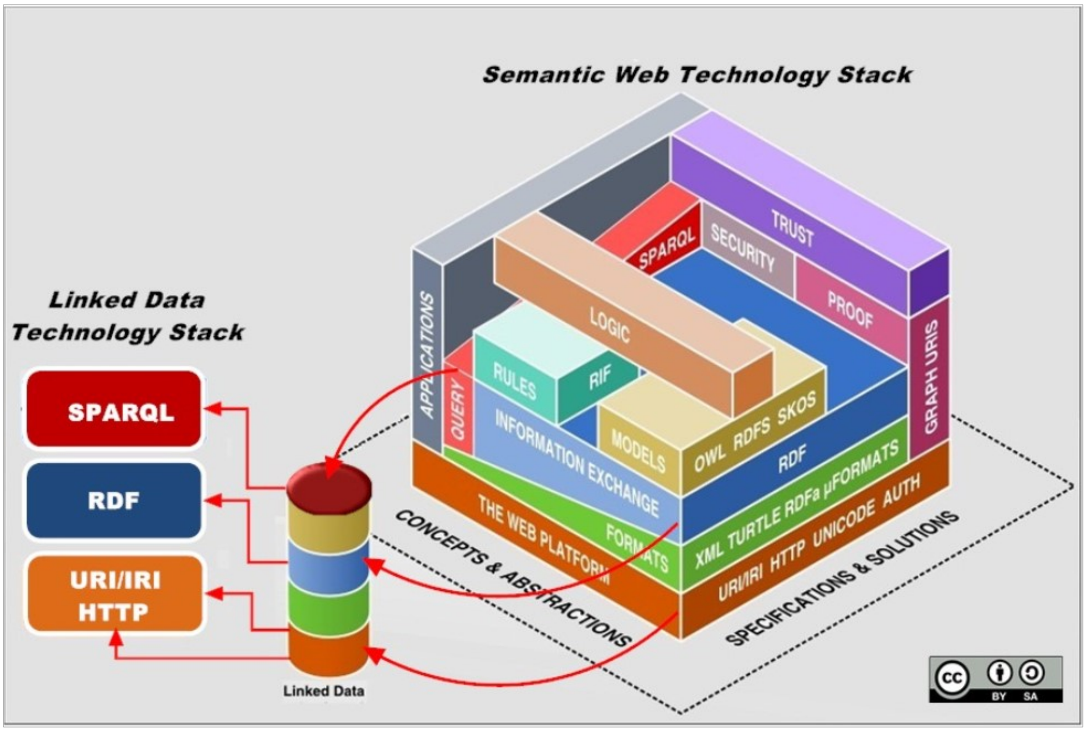

Figure 5. Isometric projection of the "technology stack" of the Semantic Web, highlighting the specifications associated with Linked Data. Adapted by Ioannis Parapontis, 2012, from Benjamin Nowack's original, 2009, (CC-BY-SA license).

Thus, Web of Linked Data means, in fact, what James Hendler (2014) calls "the Linked Data view of the Semantic Web" which essentially uses the specifications associated with the Representation and Query layers, since this approach only needs a little ontological agreement (Hendler, 2014, 25:50). This is the reason why anyone who is involved in the development of applications related to Linked Data will mostly use RDF and SPARQL and significantly less, RDF-S or OWL (Cambridge Semantics, 2016; Hendler, 2011b, 46:05).

However, given the broad view adopted in this scope for the Semantic Web, the Web of Linked Data is not understood here as a particular view of SW; rather, it is considered a specific subset of the technologies and concepts that is best tailored to the essentially unstructured environment of the WWW. This subset has been growing, as can be seen in the evolution of the diagram known as the "Linked Open Data Cloud" shown in the Figures 6 (2007) and 7 (2017).

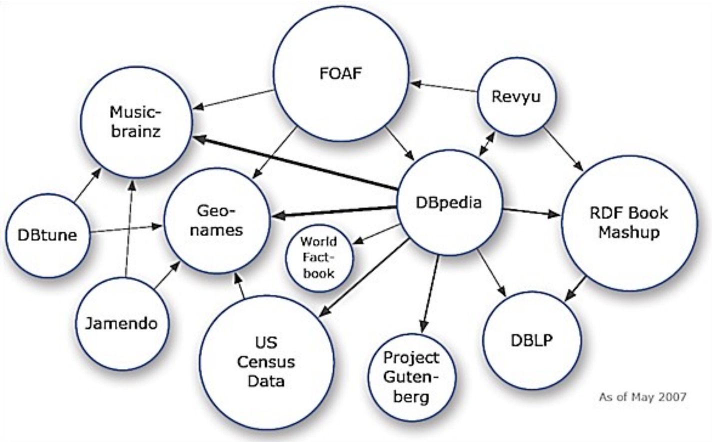

Figure 6. Diagram of the Linked Open Data Cloud in May 2007, Richard Cyganiak and Anja Jentzsch, 2014, (CC-BY-SA license).

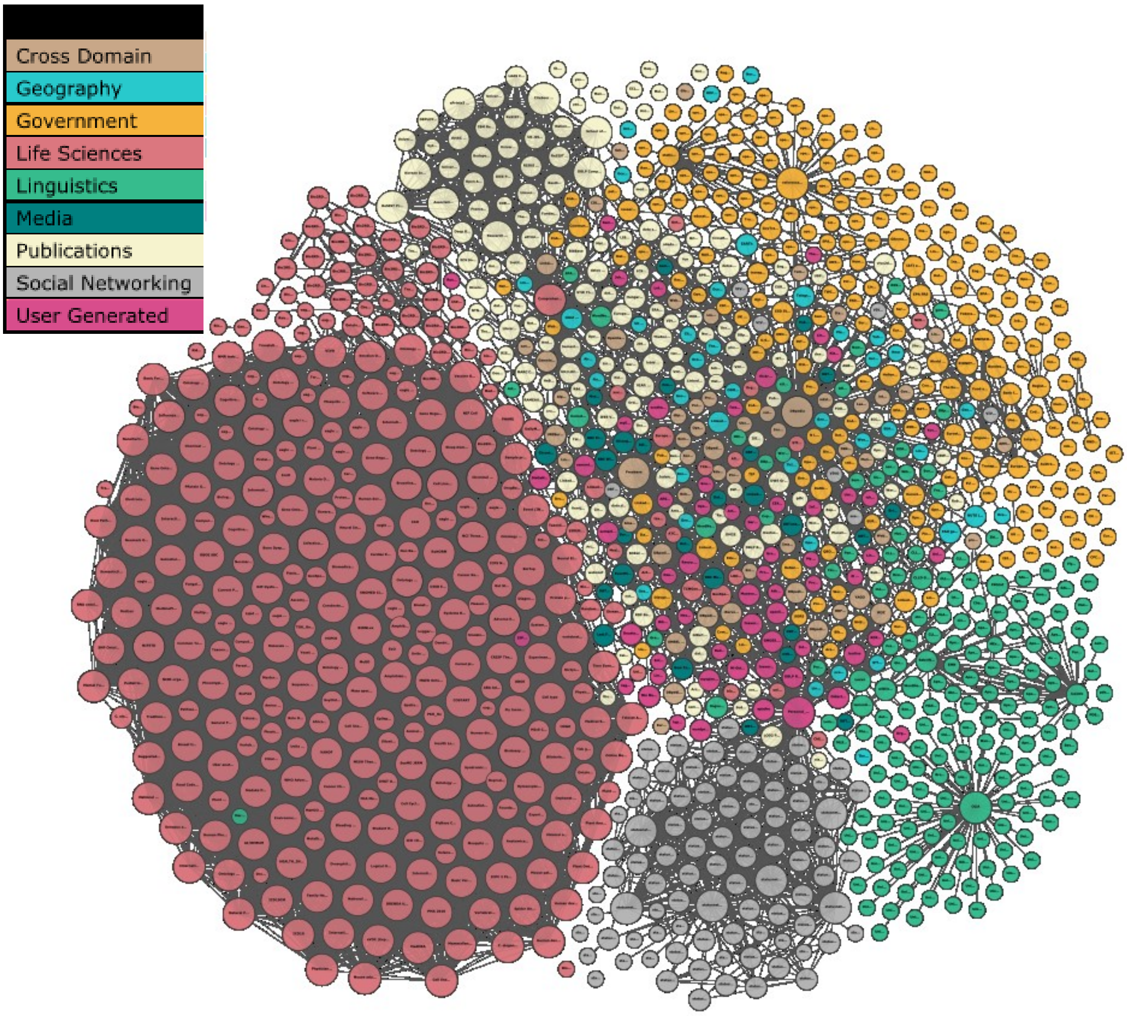

Figure 7. Diagram of the Linked Open Data Cloud in February 2017, Andrejs Abele, John P. McCrae, Paul Buitelaar, Anja

Jentzsch and Richard Cyganiak, (CC-BY-SA license).

Although it does not exhibit nowadays the same gigantic growth from the early years (about 50 times as many RDF triples in four years), we can note that the graph only shows the Linked Data in open format, not including the biggest commercial users of this particular set of "Semantic Web technologies" (Hendler, 2011a, 34:15). As the "giants", we can cite: Facebook, Google, Microsoft, Yahoo!, eBay and Oracle (Hendler, 2014, 28:30).

Despite being adopted at that pace, for the end user the SW is still almost, or even completely, unnoticed. This is explained by the fact that the success of the Semantic Web occurs behind the scenes of the "visible" Web (Hendler, 2014, 1:05; Sletten, 2014). In 2011, Ivan Herman, leader of the W3C Digital Publishing Activity, said: "we forget about the client side for web applications world" (Hendler et al., 2011), in the same line as Massimo Marchiori who, eight years earlier, claimed that people are the crucial missing part of Semantic Web (Marchiori, 2003). If we consider that: "Linked Data tends to emphasize the Web part of Semantic Web and deemphasize the Semantic parts" (Cambridge Semantics, 2016), and that the overall goal of the Web is to assist humanity (Berners-Lee, 2009, 24:45), it can be said that an important component is missing from this equation.

As mentioned, the Linked Data Web uses little semantic expressiveness. Besides RDF-S, it only uses "a very small part of OWL" (Hendler, 2011a, 26:45) and a type of knowledge organization systems also known as "light ontologies" (Hendler, 2014, 32:15).

The term "semantic expressiveness", when used in association with computational artifacts, such as the vocabularies mentioned above, is based on formal logic. The semantic and computational inference potential is based on: "identifying contents or inferring them from already recognized contents, independently (and despite) of these contents." (Marcondes, 2012, p. 63). The increase of "semantics" is gained increasing the restrictions that limit the possible interpretations of the contents represented to what is really intended to be expressed (Wassermann, 2014, 53:00). This formal semantics is the actual semantics of the SW (Almeida et al., 2011, p. 202). According to Setzer (2015) "It's only a syntactic approach expressed through an axiomatic theory or mathematical associations of its elements with operations performed by a computer."

Thus, we would expect the use of more powerful systems aiming at increasing the semantic expressiveness - such as "heavy ontologies" - to go beyond the Linked Data Web. However, these systems do not fit the open web environment, since this jeopardizes the consistency of their formal models (Hendler, 2011b, 53:00, 2014, 21:10).

In this context, we need to "bridge the gap" between the existing Linked Data Web and the knowledge representation/organization systems of greater semantic expressiveness in order to obtain an effective Data Web (Hendler, 2011b, 1:01:00, 2014, 47:35).

Conclusions

As main findings of this paper, we can state that the Semantic Web is as a comprehensive construct that includes three components: the goal of making the Web a global database dubbed as *Web of Data,* with the applications/interfaces necessary for its use; the specifications developed or associated with this purpose, particularly those responsible for the so-called Web of Linked Data, which is understood as the Web created by the connection of data using open standards; and the set of procedures and rules, called Linked Data, for the publication of data in order to allow the connection of the same to other data from different sources and formats. An illustration of the description made here can be seen in the diagram of Figure 8.

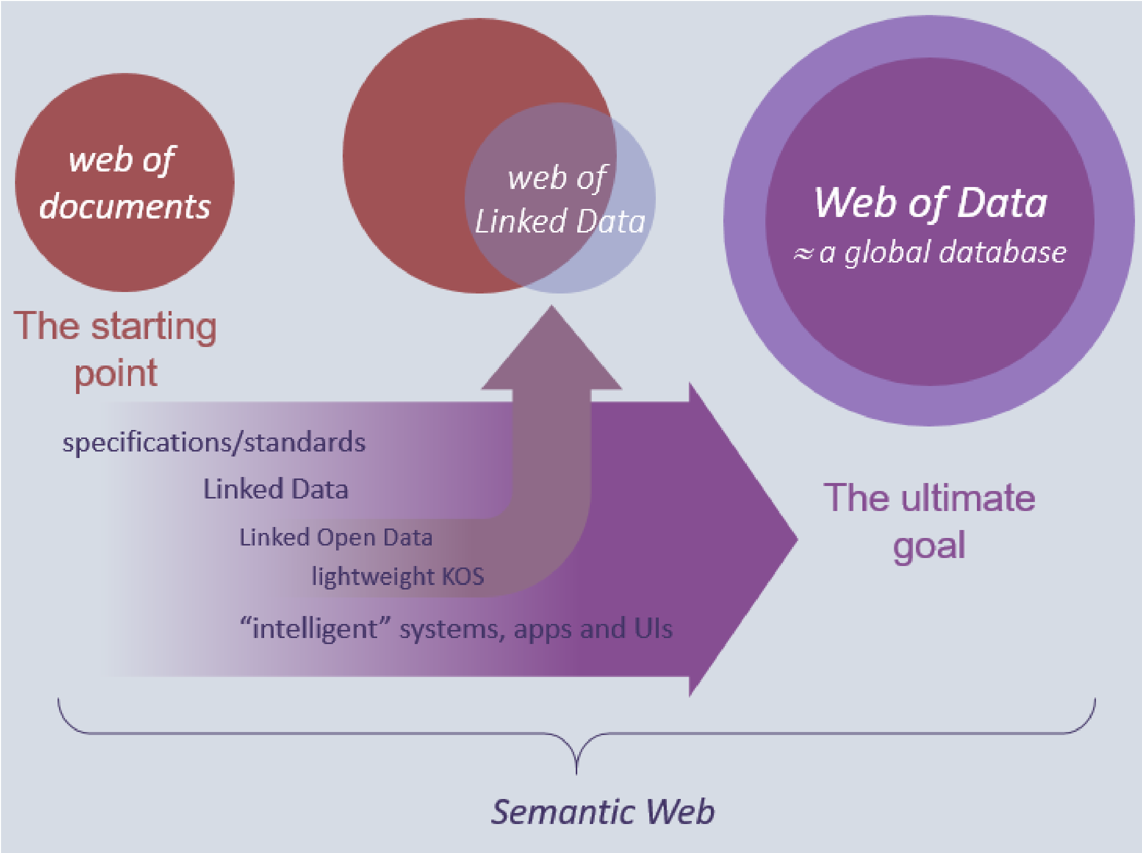

Figure 8. Proposed diagram depicting the concept of Semantic Web as a comprehensive construct that includes the goal of making the Web a global database and the set of procedures, rules and specifications developed or associated with this purpose. (source: the authors).

The hypothesis initially formulated can be confirmed, that we are witnessing an evolution, over time, in order to make the operationalization of SW more concrete and immediate. The confirmation can be made from the analysis of the three categories (*descriptive characteristics*, *structural basis* and *goals and functionalities*) related to the structural requirements necessary for the Semantic Web to become a reality.

Based on the first category, *descriptive characteristics*, we can conclude that there is a passage from the concept of *semantic* of a more abstract nature associated to the "understanding" of the information (Semantic Web), to the syntactic processing, using concrete Linked Data (Web of Linked Data), common to the computational environment.

The analysis of the second category, *structural basis*, confirmed the above mentioned trend from Semantic Web to Web of Linked Data, through the combination of three factors: (i.) the procedures related exclusively to the structuring of data for automatic processing were only observed between 1999 and 2001; (ii.) from 2006 on, there was a concentration of procedures focused on the creation of interoperability between systems and data connection; and (iii.) a direct relationship between the most recent specifications and the term Linked Data was also confirmed.

Regarding the third category, *goals and functionalities*, we have concluded that it is necessary to consider the operationalization of SW in the formal and temporal aspects. Besides, these two aspects are closely related, since the outcomes are associated with the recipients of the features offered by the W3C. If they are not restricted to end users, concrete SW functions (formal aspect), already implemented as empowering web technologies can be considered as follows: (i.) publish and link data using the RDF format; (ii.) use RDFa to make document content readable by machines; and (iii.) use the RDB2RDF standard to expose the contents of a Relational Database (RDB) in RDF format. These functions are directly related to the long-term goal of the SW which, according to the analysis presented in this paper, can be described as the use of the *Web* as a global database.

The other three concepts: Web of Data, Web of Linked Data and (simply) Linked Data, can be taken as a continuum with a descending order, as follows:

- Web of Data is the ultimate goal presented for the Semantic Web;
- Web of Linked Data is a specific part of this purpose and
- Linked Data is a specific aspect of that part.

Starting with the latter, the concept of Linked Data refers to the set of procedures and rules for the publication of data in order to enable them to be linked to other data from different sources. These procedures can be applied both inside and outside the Web environment; as they can be used with data in open format (Linked Open Data) or proprietary format.

We also concluded that the so-called Web of Linked Data is the combination of these procedures applied in a Web environment, using open data standards and following the SW specifications associated to the stack layers: a) representation; b) query; and c) a subset of the reasoning layer, specifically, the light knowledge organization systems (“light ontologies”).

Regarding the difference between the Web of Linked Data and the Web of Data, we can highlight the limitations of the former - both in the reach of the linking possibilities and also on the semantic attributed to them. In the scope of this study, the Web of Data is an enlarged Web that arises as a result of the development of the Semantic Web technologies, in which it is possible to carry out queries similarly to those usually made in databases. In order for this “vision” to come true, it is necessary to unite two still tenuously connected outcomes: the virtually unlimited possibility of connections between data - reified in the web domain - with the potentiality of the automated inference of “intelligent” systems - that would be the “semantic” component.

As a final remark, we understand that theoretical and critic contributions to the process of building and differentiating concepts is part of the science making process, and our contribution aimed at helping the understanding of the cartography of the subjects in scope. The Semantic Web propelled promises and changes are felt as unrealized by many actors in the information science and technology area, perhaps because of the terminological metamorphosis we have tried to described.

We believe that mapping these changes and contextualizing the various concepts in a comprehensive framework are a contribution to the field. We understand that the present study allows us to have a holistic and systematic view of the whole conceptual landscape involved (summarized in Figure 8), which is, otherwise, found in different statements dispersed in several documents. We hope, in this way, to contribute to the interdisciplinary understanding of the subject, to foster its discussion, interpretation and appropriation

As future work, and shed by the theoretical light of these findings, we can envision the analysis of the W3C SW technology evolution, from XML to contemporary proposals like the Efficient Extensible Interchange (EXI), as a mean to fulfill the original views and the manyfold paths it took since then. We also consider relevant the analysis of the concept of Web of Data, comparing the initial formulation as a global database and the current state that mixes all sort of data types, ranging from CSV files to RDF links (Lehmann et al., 2017, p. 1680).

References

Ali Shiri, M. C. (2015). Understanding Semantic Web: a conceptual model. *Library Review*, 64(1/2), 82–100. https://doi.org/10.1108/LR-09-2014-0097

Almeida, M. B., Souza, R. R., & Fonseca, F. (2011). Semantics in the Semantic Web: A critical evaluation. *Knowledge Organization*, *38*(3), 187–203.

Bardin, L. (2011). *Análise de conteúdo*. (L. A. R. A. Pinheiro, Trans.). São Paulo: Almedina.

Berners-Lee, T. (1990, May). Information Management: A Proposal. Retrieved May 2, 2018, from https://www.w3.org/History/1989/proposal.html

Berners-Lee, T. (1994, September). Plenary at WWW Geneva 94. Retrieved April 26, 2018, from https://www.w3.org/Talks/WWW94Tim/

Berners-Lee, T. (1998, October 14). A roadmap to the Semantic Web. Retrieved March 21, 2016, from https://www.w3.org/DesignIssues/Semantic

Berners-Lee, T. (2006). The World Wide Web: Past, present and future (FAQ). Retrieved March 16, 2016, from http://www.w3.org/People/Berners-Lee/FAQ.html

Berners-Lee, T. (2009). Web 2.0 Summit 09 discussion: A Conversation with Tim Berners-Lee interview by Tim O'Reilly [video]. San Francisco: O'Reilly Media. Retrieved from https://youtu.be/KY5skobffk0

Berners-Lee, T. (2010). Long Live the Web. *Scientific American*, *22*(December), 80–85. Retrieved from https://jblomo.github.io/webarch253/slides/Long_Live_the_Web.pdf

Berners-Lee, T. (2018, March 29). Longer Biography. Retrieved March 30, 2018, from https://www.w3.org/People/Berners-Lee/Longer.html

Berners-Lee, T., & Fischetti, M. (2000). *Weaving the Web: The Original Design and Ultimate Destiny of the World Wide Web by Its Inventor*. HarperCollins.

Berners-Lee, T., Hall, W., Hendler, J. A., O 'hara, K., Shadbolt, N., & Weitzner, D. J. (2006). A Framework for Web Science. *Foundations and Trends in Web Science*, *1*(1), 1–130. https://doi.org/10.1561/1800000001

Berners-Lee, T., & Hendler, J. A. (2001). Publishing on the Semantic Web. *Nature*, *410*(April), 1023–1024. Retrieved from https://github.com/AKSW/semann/blob/master/pdf/T.B. Lee - Publishing on the semantic web.pdf

Berners-Lee, T., Hendler, J. A., & Lassila, O. (2001). The Semantic Web. *Scientific American*, *284*(5), 35–43.

Bikakis, N., Tsinaraki, C., Gioldasis, N., Stavrakantonakis, I., & Christodoulakis, S. (2013). The XML and Semantic Web Worlds: Technologies, Interoperability and Integration. A survey of the state of the art. In I. E. Anagnostopoulos, M. Bieliková, P. Mylonas, & N. Tsapatsoulis (Eds.), *Semantic Hyper/Multimedia Adaptation* (pp. 319–360). Berlin: Springer. https://doi.org/10.1007/978-3-642-28977-4_12

Bizer, C., Heath, T., & Berners-Lee, T. (2009). Linked data - The story so far. University of Southampton, ePrints Soton. Retrieved from http://eprints.soton.ac.uk/271285/

Cambridge Semantics. (2016). Many Names for the Semantic Web. Retrieved May 15, 2017, from http://www.cambridgesemantics.com/semantic-university/many-names-semantic-web

Codina, L. (2003). La web semántica: una visión crítica. *El Profesional de La Información*. Retrieved from http://www.elprofesionaldelainformacion.com/contenidos/2003/marzo/16.pdf

Delattre, P. (1981). *Teoria dos sistemas e epistemologia*. (J. A. Furtado, Trans.). Porto: A Regra do Jogo.

Feigenbaum, L. (2011). The Semantic Web Landscape: A practical introcdution [Video]. In *Cambridge Semantic Web Meetup*. Cambridge Semantics. Retrieved from https://supportcenter.cambridgesemantics.com/semantic-university/the-semantic-web-landscape-a-practical-introduction

Hampton, J. A. (2016). Concepts in the Semantic Triangle. In E. Margolis (Ed.), *The Conceptual Mind: New Directions in the Study of Concepts*. The MIT Press.

Heath, T. (2009, March 2). Linked Data? Web of Data? Semantic Web? WTF? Retrieved April 30, 2018, from http://tomheath.com/blog/2009/03/linked-data-web-of-data-semantic-web-wtf/

Hendler, J. A. (2011a). Semantic Web: “10 year update” [video]. Retrieved from http://www.vestforsk.no/video/wims/wims11-jahendler-keynote.ogv

Hendler, J. A. (2011b). “Why the Semantic Web will never work” (note the quotes) [Video]. Retrieved from https://youtu.be/oKiXpO2rbJM

Hendler, J. A. (2014). The Semantic Web: The Inside Story [video]. In *Summer School in cognitive Science: Web Science and the Mind*. Montréal: Institut des sciences cognitives, UQAM. Retrieved from https://youtu.be/3Ap5FsxvjTQ

Hendler, J. A., Berners-Lee, T., & Miller, E. (2002). Integrating Applications on the Semantic Web. *Journal of the Institute of Electrical Engineers of Japan*, *122*(10), 676–680. Retrieved from http://www.w3.org/2002/07/swint

Hendler, J. A., Hausenblas, M., Hepp, M., Horrocks, I., Welty, C., & Herman, I. (2011). Semantic Web Death Match 2011: Industry vs. Academia vs. Standards [video]. In *10th International Semantic Web Conference (ISWC)*. Bonn. Retrieved from http://videolectures.net/iswc2011_panel/

Hendler, J. A., Shadbolt, N., Hall, W., Berners-Lee, T., & Weitzner, D. J. (2008). Web science: An interdisciplinary approach to understanding the Web. *Communications of the ACM*, *51*(7), 60–69. https://doi.org/10.1145/1364782.1364798

Lehmann, J., Auer, S., Capadisli, S., Janowicz, K., Bizer, C., Heath, T., … Berners-Lee, T. (2017). LDOW2017: 10thWorkshop on Linked Data on theWeb. In *Proceedings of the 26th International Conference on World Wide Web Companion - WWW ’17 Companion* (pp. 1679–1680). New York: ACM Press. https://doi.org/10.1145/3041021.3055510

Kuckartz, U. (2014). *Qualitative Text Analysis: A Guide to Methods, Practice and Using Software*. (K. Metzler, Ed.). London: SAGE Publications Ltd.

Kuhn, T. S. (1996). Postscript - 1969. In *The structure of scientific revolution* (3rd ed., pp. 174–210). Chicago: Unirversity of Chicago Press.

Marchiori, M. (2003). The Semantic Web Made Easy. Retrieved May 15, 2016, from https://www.w3.org/RDF/Metalog/docs/sw-easy

Marcondes, C. H. (2012). Em busca de uma semântica do digital, ou “As they may think.” *PontoDeAcesso*, *6*. Retrieved from http://www.portalseer.ufba.br/index.php/revistaici/article/viewArticle/6103

Parapontis, I. (2012, December 7). Web of Data Stories: Semantic Web Technology Stack(s). Retrieved October 2, 2017, from https://ioannis.parapontis.com/2012/12/07/semantic-web-technology-stacks/

Parreiras, F. S. (2012). *Semantic Web and Model-driven Engineering*. Piscataway: John Wiley & Sons, Inc.

Patel-Schneider, P. F., & Horrocks, I. (2007). A comparison of two modelling paradigms in the Semantic Web. *Web Semantics*, *5*(4). https://doi.org/10.1016/j.websem.2007.09.004

Ray, K. (2010). Web 3.0 [Video]. Retrieved from https://vimeo.com/11529540

Setzer, V. W. (2015, May 25). Dado, informação, conhecimento e competência. Retrieved May 14, 2016, from https://www.ime.usp.br/~vwsetzer/dado-info.html

Sletten, B. (2014, January 13). Keep On Keeping On. Dataversity, Smart Data. Retrieved from http://www.dataversity.net/keep-on-keepin-on/

Souza, R. R., & Alvarenga, L. (2004). A Web Semântica e suas contribuições para a ciência da informação. *Ciência Da Informação*, *33*(1), 132–141. Retrieved from http://ref.scielo.org/mp2fh8

van de Ven, A. H. (2013). *Engaged scholarship: A guide for organizational and social research*. Oxford: Oxford University Press.

van den Heuvel, C. (2009). Web 2.0 and the Semantic Web in Research from a Historical Perspective. The designs of Paul Otlet (1868-1944) for telecommunication and machine readable documentation to organize research and society. *Knowledge Organization*, *36*(4), 214–226

van den Heuvel, C., & Rayward, W. B. (2011). Facing interfaces: Paul Otlet's visualizations of data integration. *International Review of Research in Open and Distance Learning*, *62*(12), 2313–2326. https://doi.org/10.1002/asi.21607

Wassermann, R. (2014). Ontologia e Representação do Conhecimento [video]. *O Estado Da Arte*. São Paulo: IPTV USP/ECA. Retrieved from http://iptv.usp.br/portal/video.action?idItem=25631

World Wide Web Consortium. (2013a, June 27). SemanticWeb W3C - Wiki. Retrieved March 24, 2017, from https://www.w3.org/wiki/Semantic_Web

World Wide Web Consortium. (2013b, December 11). W3C Semantic Web Activity Homepage. Retrieved May 1, 2018, from https://www.w3.org/2001/sw/

World Wide Web Consortium. (2015a). W3C Standards: Linked Data. Retrieved May 1, 2018, from http://www.w3.org/standards/semanticweb/data

World Wide Web Consortium. (2015b). W3C Standards: Semantic Web. Retrieved May 1, 2018, 2016, from https://www.w3.org/standards/semanticweb/

World Wide Web Consortium. (2017a, October 11). Semantic Web Wiki. Retrieved May 1, 2018, from https://www.w3.org/2001/sw/wiki/Main_Page

World Wide Web Consortium. (2017b). W3C Data Activity: Building the Web of Data. Retrieved May 1, 2018, from http://www.w3.org/2013/data/

Yin, R. K. (2014). *Case study research: Design and methods* (5th ed.). London: SAGE Publications.