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A Review on Semantic Web and Recent Trends in Its Applications

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***Abstract*—Semantic web works on producing machine readable data. So semantic web aims to overcome the amount of data that is consisted. The most important tool to access the data which exist in web is the search engine. Traditional search engines are insufficient in the face of the amount of data that is consisted as a result of the existing pages on the web. Semantic search engines are extensions to traditional search engines and improved version. This paper summarizes semantic web, traditional and semantic search engine concepts and infrastructure. Also semantic search approaches and differences from traditional approach are detailed. A summary of the literature is provided by touching on the trends on this area. In this respect, type of applications and the areas worked for are considered. Based on the data for two different years, trend on these points are analyzed and impacts of changes are discussed. It shows that evaluation on the semantic web continues and new applications and areas are also emerging.**

Keywords-semantic web; semantic search; search engine; trends

I. INTRODUCTION

World Wide Web changes the way of sharing knowledge which used to be by the printed documents having a lot of limitations. Web browsers enable users to pass the information space by hypertext links. Search engine, on the other hand, indexes web documents and analyze links structures for interpolation of potential suitability between search strings and links. This functionality is the result of public, open and extensible nature that is seen as the main feature of unconstrained web growth [1].

When the development of web is considered, traditional approaches appears insufficient. There is no official numbering for web that is developing after the HTTP protocol is defined. Web 1.0 (1995-2000) holds static structure that only provides document sharing. In web 2.0 (2000-2010) content consists of user entries and shares, e.g. Wikipedia, Flicker, Youtube, Facebook and etc. As a result of searching a keyword in current web, millions of results are listed. It is highly difficult to decide on which result is more valuable or relevant. Instead of human interference on the selection, there is a need to make decision automatically.

Contrary to traditional approaches, semantic is new alternative way for solution to that. Tim-Berners Lee defined semantic web simply: web of data that is processed by machines directly or indirectly [2]. Web 3.0 (2010-) or semantic web can be defined as a web: knowledge has clearly and well defined meaning, provide the structure of the meaningful content of Web pages, machines process and understand the data, and computers work in cooperation with people [3].

Semantic web renders the documents to machine readable format by adding semantics. Therefore, in the web a transformation to data instead of documents dominance is started. However, the change until now is very limited. Most web pages are in different forms of unformatted text or data [4].

Several different types of studies are going on semantic web. These covers application context as well as application types. In this study we try to analyze these topics in order to get the future implications.

II. SEMANTIC WEB

In this part general description of the concept is explained. Some protocols and standards for semantic web are defined by W3C. Fig.1 shows the semantic cake and illustrates the concepts [5]. In semantic web objects or concepts are ambiguously referred by these protocols.

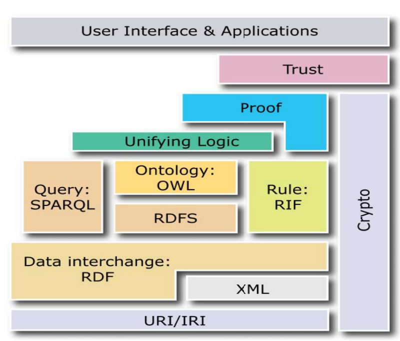

Figure 1. Layercake diagram

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a) Uniform Resource Identifier : Any kind of object or concept is identified by *URI [1]*. Uniform Resource Identifier (URI) is used for resource definition [6].

b) Extensible Markup Language (XML): It is a simple, flexible text format derived from Standard Generalized Markup Language and designed to overcome the challenges of large-scale electronic publishing [7]. XML is used for syntactic representation [6].

c) Resource Description Framework (RDF): It is the first language developed for semantic web. RDF purposes to add machine readable metadata to web resources [6]. Semantic web purposes current web unstructured documents to web of data with RDF [2]. RDF is simple, general-purpose metadata language. It provides conceptual modeling knowledge. RDF comprises of subject-predicate-object triples about an object [1, 6].

d) RDFS: It provides a data-modelling vocabulary for RDF data *[8]* and it is a simple data typing model for RDF.

e) Web Ontology Language (OWL): It is an ontology language which describes inherent classes and relations in web documents and applications [9]. Things, groups of things and relations between things are represented rich and complex by OWL [10].

f) SPARQL: *SPARQL* is query language for RDF [11].

B. Semantic Approaches

There are four semantic approaches. Semantic search engines use one or more of these approaches. Semantic approaches are mixed and matched by semantic search engines for providing unique searching experiment to users. Fig. 2 shows the intersection of approaches. Initial point of semantic search is using semantics for improving searching experiments [12].

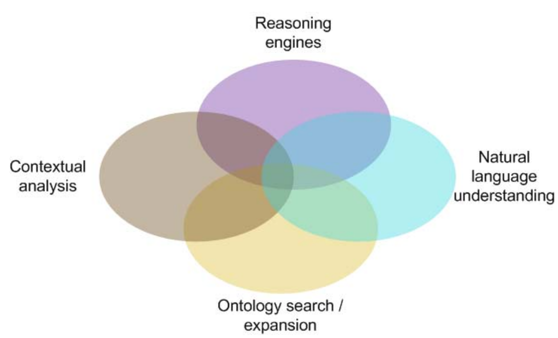

Figure 2. Semantic web approaches.

1) Contextual analysis: Queries are disambiguated by contextual analysis. For example 'strike' refers baseball, labor or something else.

2) Reasoning engines: Additional facts can be inferred from set of facts that are represented in the system. If the system knows someone's children, and knows his children too, then the reasoning system infer a grandchildren.

3) Natural language understanding: The content and user queries are processed by this approach to identify the intended knowledge. The syntax of the sentence and rules are used to identify people, places, organizations, and etc.

4) Ontology search: Ontology is used to represent knowledge about a domain. Queries are expanded by adding terms from relevant ontology to broad involvement.

III. SEMANTIC SEARCH VS TRADATIONAL SEARCH

The transformation of web aims faster and more accurately knowledge retrieval. This is possible with search operation. In other words search shows the differences between traditional web and semantic web. So the semantic search is considered as core of the semantic web. Thus the search is included in this part.

Search process is affected by semantic webs' features. The distinguishing features are listed below [13]:

- All objects of real world are involved in the search process.
- Knowledge is understandable for machine as well as human.
- Semantic web languages are well structured than HTML.
- A single concept can be represented by distributed knowledge.

These features cause fundamental differences to traditional search engines. They are listed below [13]:

- Intelligent retrieval is provided by using a logical framework.
- In documents metadata maintenance, update and more complex ranking is resulted by complex relations.
- Visualization techniques are required for visualization of search results by specifying relationships among objects

Synonyms, variants and subtypes are supported by semantic search engines. Search results should be evaluated according to closeness between user query and matches. There are two types of semantic evaluation, direct matches that is included synonyms and related matches that is based on semantic relationships [14].

A. Search Types

There are two very different search types. The differences between them are explained below.

a) Navigational Searches: This is a search type that user inputs a phrase or combination of words that is expected to find in web documents. The keywords do not denote a concept. User navigates particular intended documents or a spesific site (e.g., search Karabük University Computer Engineering homepage) by this type of search [2, 15].

b) Research Searches: In this type of search the user inputs a keyword that denote a search concept. User does not know a particular document but tries to locate a document to find search concept [2]. In literature most commonly this type of search is found voice in informational searches. User seek information on topic (e.g., search "what is semantic?") [16].

Semantic search tries to improve the results of searches. Traditional search engines results a list, but semantic search augment this list with relevant data pulled out from semantics. In addition, trying to understand concepts denoted by the search phrase improve the accuracy [2].

B. Constraints of Traditional Search Engine

Web is the global database and most web pages are in web 2.0 structure. So there exists lack of semantic structure. Therefore the infrastructure of current web is not suitable for machine learning. As a result, the search engines return the ambiguous or partially ambiguous results of data set. Semantic web is an extension of web and is developed to overcome the constraints of web that is listed below [12]:

- Web content is not in suitable structure for representation of information.
- Ambiguity of knowledge is resulted in poor interconnection of concepts.
- It is not possible to ensure trust at all levels for enormous number of users and content.
- A universal format is not provided for machines to understand the information.
- There is no structure for automatic information transfer.

The relevant many indexed resources are missed (silence/lack of sensitivity), completely irrelevant innumerable hits (noise/lack of specificity) that requires typically user selection, are returned by existing search engines. The reasons are listed below [17]:

- The sought page uses synonym of the word referring to the concept.
- Spelling mistakes and variants are considered as different terms.
- Search engines cannot manipulate HTML intelligently and cannot succeed content meaning of different web resources and up-to-date context.

In addition, traditional search engines cannot be used for semantic web documents for following reasons [13]:

- Semantic tags are not allowed to be indexed and retrieved by current techniques.
- Meanings of tags are not used.
- Results are not shown in visual form.
- Ontologies may have cross references although they are not separated entities.

Search engines should search semantic concepts and their relations of knowledge in web pages instead of searching through word matching. Contrary to traditional search engine, semantic search engine aims a new generation web that is supported semantics and machine readable context [14].

C. Search Engine Structure

Search engine is a tool that searches knowledge by using specific code with some strategies, organizes the knowledge and after processing the knowledge returns to users. Search engine is responsible for providing search service to users [18].

Search engine is main tool for looking for knowledge in web. In generally search engines are composed of five basic components: a crawling module, an indexing module, a page ranking module, a search module, and a page repository [19]. Structure of traditional search engine involves these five basic modules least. But they comprise different numbers of components. Similar structure is loosely used by semantic search engines [13, 20]. In addition, the semantic search engines use the consolidation and reasoning modules [20]. Fig. 3 illustrates the structure of semantic search engine with detailed nine modules [18, 20]. These parts are briefly explained below.

*1) Consolidation: T*his module attempts to detect synonymous identifiers in target data and to match them.

2) Reasoning: Source of data is implemented in new form by the component using inherent semantics.

3) Crawler: It continually collects data from internet by crawling and sends them to search engines' database. Crawler starts with an empty set initially, visits a unique web page, retrievals web page information and sends it to a set and search engines' database non-stop [18]. Crawler creates local copy of web pages and periodically updates. Main factor to update is change rate [19].

4) Document Parser: Original documents that the crawler finds automatic are parsed by Document Parser. Main function of parsing is filtering file information. So the index output is provided a property way.

5) Analyzer: It divides the document sources that are parsed by parser. It separates text information to smallest units. Both indexing and search process need parsers. In order to obtain accurate results same parser must be used.

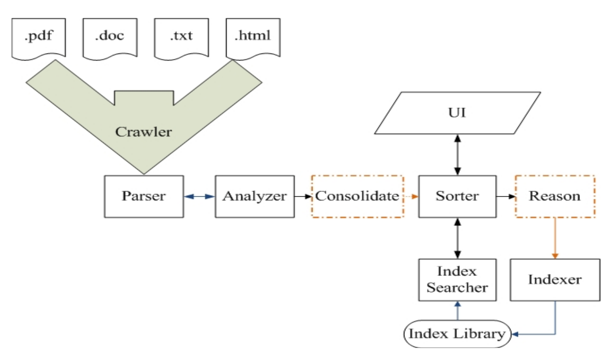

Figure 3. Search engine structure.

6) Indexer: It is needed to preprocess the documents and to have a data structure which makes it possible to easy search among documents. This type of data structure is index. When search engines handle huge amount of documents, index significantly increases the speed of searching knowledge.

7) Index searcher: It takes user search requests from user interface, searches in index library with specific strategy and sends results to sorter and filtering system.

8) Sorter and Filter: It is not sufficient for the document to be searched by index searcher. It is also required for query results to be sorted. To be relevant with query is essential to be in front. Term weight represents significance of a term for a document. A weight term plays an important role in calculating relevancy of documents [18]. Ranking indicates importance of searched element with score [20].

9) User Interface: This module is responsible for human-computer interaction functions, to receive queries from user, to deploy query to index searcher and to show searched and filtered results to user [18].

IV. Investigation Of Applications On Semantic Web

Application trends in semantic web can give implication on the future technology and works. Domains of semantic web technologies are identified by W3C. In this respect, activities of registered web cities are investigated in terms of semantic web [21].

In literature, evaluation of applicability of semantic web is studied by V. Janev and S. Vraneš in 2011 [22]. In their study, semantic web is investigated in terms of applied areas and application context for 42 case studies and use cases.

In this study similar perspective is used to find out detailed and up-to-date trends on web semantic studies. Totally 48 entries of case study (35) and use case (13) are analyzed for 81 applied areas, 126 application contexts, and 187 technologies [21].

In three years, registered case studies and use cases are increased from 42 entries to 48. Besides these registered cases there might be few more entries which are not registered.

Table I shows 18 application context and their coverage. The relations between applied areas and semantic web technologies' application context are showed in Table II. On the other hand the relations between application context and semantic web technologies used can also be seen in Table III.

In this study three coverage columns are presented. The *2011 Unnormalized Ratio of Coverage* column shows the results done by V. Janev and S. Vraneš [22]. The current results are shown in *2014 Unnormalized Ratio of Coverage* column and *2014 Normalized Ratio of Coverage* column in different respective. In Table I each entry is classified in one or more application context. And also in Table II and Table III for each row applied area and technology is classified in one or more application context. For example although public institution has 17 entries, totally they are classified in 43 application context. Thus these coverage columns represent related percentage and so total percentage is more than one hundred. We also want to represent the coverage in simple way. So the coverage is normalized and values can be seen in *2014 Normalized Ratio of Coverage* column. 81 applied areas, 126 application contexts, and 187 technologies are used for normalize instead column data instead of using 48 entry. Therefore total coverage is one hundred in this column. Unnormalized values are used to compare the results with former study, and to observe the changes in the trend.

It can be seen from Table I that intensity of applications is in data integration, improved search, portal, content discovery, semantic annotation and content management. The rank is changed in three years due to inclusion of new application context. Improved search which can be achieved only by semantic search is used to improve traditional search results by using not just words, but concepts and logical relationships [22]. Coverage of this type of search is increased by 2.92 percent from 45% to 47.92%. On the other hand new application areas such as portal are also emerging.

The most common area among application contexts is data integration. This implies that transformation of web 2.0 to web 3.0 continues. Improving search speed and accuracy is second popular trend. Transformation of web 2.0 to web 3.0 is started with discover content. It continues with semantic annotation generation and content management.

The most popular applied area is institutional with 32.10% (public institution and eGoverment, cumulatively). On the other hand 54.17% of applications are on institutional. In three years despite slight decrease in its coverage, still it is on the top. The reason for the decrease can be explained by private sector involvement in semantic web applications. Besides that, inclusion of new types of applied areas can be considered as also reason for that. Addition of new types of applied areas shows semantic web is getting more involved in different respects.

While content discovery applications slow down, content management applications are getting more involved. This shows that people started to involve on content management beside content discovery. Semantic annotation decreases 1.08 percent. This is incomprehensible since generation of semantic annotation comes after the content discovery and management process.

From Table II, changes in applied areas can be seen. In three years time, e-government coverage has the highest increase with 1.75 percent and it is followed by health care with 0.5 percent. The most declines occurred in IT industry with 1.58 percent. There is also decrease in public institution coverage by 0.58 percent. Although these figures show some implication in trends, it has to be kept in mind that the number of coverage areas is increased in 2014.

It can be seen from Table II that, the most used semantic web technologies is steel RDF(S). It is used in 77.08% of applications. On the other hand, about 20% of application types use this technology. The other most used semantic web technologies are in-house vocabularies, OWL, public vocabularies and SPARQL. In last three years although their ranks are stayed same, their ratios are slightly changed. RDF(S) technology coverage is reduced to 81% by 3.92. In-house vocabularies technology is increased by 0.58 from 64% to 64.58%. The coverage of OWL technology is identical. Public

TABLE I. SEMANTIC WEB TECHNOLOGIES' APPLICATION CONTEXT

Id	Application Context			
	Context	***2011 Unnormalized Ratio of Coverage (%) [22]***	***2014 Unnormalized Ratio of Coverage (%)***	***2014 Normalized Ratio of Coverage (%)***
1	Data integration	67	66.67	25.40
2	Improved search	45	47.92	18.25
3	Portal		35.42	13.49
4	Content discovery	26	27.08	10.32
5	Semantic annotation	24	22.92	8.73
6	Content management		12.50	4.76
7	Domain modeling		8.33	3.17
8	Social networks	10	8.33	3.17
9	Service integration	5	6.25	2.38
10	Customization		6.25	2.38
11	Provenance tracking		4.17	1.59
12	Natural language interface	5	4.17	1.59
13	Simulation and testing		2.08	0.79
14	Lifecycle management		2.08	0.79
15	Text mining		2.08	0.79
16	Repair and diagnostic help		2.08	0.79
17	Schema mapping		2.08	0.79
18	Modeling		2.08	0.79

vocabularies technology is reduced to 48% by 0.08. And also SPARQL is increased by 3.58 from 36% to 39.58%.

The most used semantic web technology is still RDF(S) since it is relatively easy to implement. And also trend is reasonable because of considering the expressivity and performance together.

V. TREND OF RESEARCHS

In this study, we also tried to infer the trend of researches on semantic web. In 2013, roughly semantic web papers focused on ontology are about 59 percent, search engine and text retrieval are about 12 percent, and rest of the papers are classified as multimedia retrieval, evaluation of search engine and concepts. Ontology is one of the main topics of semantic and many researches continue to work on in this topic. The search engine is still one of the topics that draw attention by the researchers. Studies on semantic web started with text retrieval and future studies seem to concentrate on multimedia retrieval. For both text and multimedia, the evaluation is key topic to assess the results.

TABLE II. RELATION BETWEEN APPLIED AREA AND SEMANTIC WEB TECHNOLOGIES' APPLICATION CONTEXT

Applied area	**Semantic Web Application Context**																				
	2011 Unnormalized Ratio of Coverage (%) [22]	***2014 Unnormalized Ratio of Coverage (%)***	***2014 Normalized Ratio of Coverage (%)***	***Data integration***	***Improved search***	***Portal***	***Content discovery***	***Semantic annotation***	***Content management***	***Domain modeling***	***Social networks***	***Service integration***	***customization***	***provenance tracking***	***natural language interface***	***simulation and testing***	***lifecycle management***	***text mining***	***repair and diagnostic help***	***schema mapping***	***modeling***
(17) public institution	36	35.42	20.99	11	10	9	3	4	1	2	1		1							1	
(9) eGovernment	17	18.75	11.11	4	7	5	2	1													
(6) health care	12	12.50	7.41	6	3		1	1	1					2						1	1
(5) IT industry	12	10.42	6.17	3	1	2		2			2				1						
(4) telecommunications	10	8.33	4.94	2	1		1	1				1	1		1						
(4) publishing		8.33	4.94	4	3	2	2	3	2	2			1								
(4) life sciences	7	8.33	4.94	4	2	2	2	1	1					1				1			1
(3) library	7	6.25	3.70	3	3	2		2	2	3			1								
(3) energy	7	6.25	3.70	3	1	2		1	1		1										
(3) automotive	5	6.25	3.70	1	1				1	1						1			1		
(3) museum		6.25	3.70	3	2	3		1	1	2			1								
(2) legal		4.17	2.47	1	2	1															
(2) search		4.17	2.47	1	2	1	2	1	1				1	1							1
(2) broadcasting	7	4.17	2.47	2	2		2														
(2) oil & gas		4.17	2.47	2	1	2		1													
(1) learning technology		2.08	1.23	1			1	1	1												
(1) arts and education		2.08	1.23				1														
(1) service management		2.08	1.23	1								1					1				
(1) education		2.08	1.23	1			1	1	1												
(1) application lifecycle management		2.08	1.23	1								1					1				
(1) web accessibility		2.08	1.23		1																
(1) cultural heritage		2.08	1.23	1	1	1			1	1											
(1) utilities		2.08	1.23	1					1		1										
(1) financial		2.08	1.23				1														
(1) semantic desktop		2.08	1.23	1	1		1	1				1									
(1) geographic information system		2.08	1.23	1																	
(1) eTourism		2.08	1.23	1		1															

TABLE III. RELATION BETWEEN SEMANTIC WEB TECHNOLOGIES USED AND SEMANTIC WEB TECHNOLOGIES' APPLICATION CONTEXT

Technologies	2011 Unnormalized Ratio of Coverage (%) [22]	2014 Unnormalized Ratio of Coverage (%)	Semantic Web Application Context																		
			2014 Normalized Ratio of Coverage (%)	Data integration	Improved search	Portal	Content discovery	Semantic annotation	Content management	Domain modeling	Social networks	Service integration	customization	provenance tracking	natural language interface	simulation and testing	lifecycle management	text mining	repair and diagnostic help	schema mapping	modeling
(37) RDF(S)	81	77.08	19.79	23	14	14	12	9	3	1	4	2	2	2	2		1	1	1		1
(31) in-house vocabularies	64	64.58	16.58	19	15	14	10	4	2	2			1	1	2	1		1	1		
(24) OWL	50	50.00	12.83	16	13	9	7	7	1	2	1	1	2	2	1				1	1	1
(23) public vocabularies	48	47.92	12.30	17	13	10	9	6	5	2	2		1	2						1	1
(19) SPARQL	36	39.58	10.16	15	10	4	4	7	5	2	4	1	1	1	1					1	1
(10) public datasets		20.83	5.35	8	6	3	3	4	4	2	1		1	1							1
(10) RDF		20.83	5.35	8	8	3	2	4	4	3	1		1								
(7) Rules	14	14.58	3.74	5	1	2	1	1						1	1	1					
(5) RDFa	7	10.42	2.67	3	4	2	2	2	4	2			1								
(5) SKOS	10	10.42	2.67	3	4	3	3	3	3	2											
(4) Rules (N3)		8.33	2.14	3	1		1	1	1					2	1						1
(2) GRDDL	5	4.17	1.07	1	1	1	1						1								
(2) OWL DL		4.17	1.07	2	1	2		1		1			1								
(1) SeRQL		2.08	0.53	1	1	1	1														
(1) eRDF		2.08	0.53		1	1	1						1								
(1) OWL-S		2.08	0.53	1		1															
(1) RDFS		2.08	0.53	1	1	1			1	1											
(1) Rules (F-logic)		2.08	0.53	1												1					
(1) RDFS++		2.08	0.53	1	1		1	1				1									
(1) WSMO	2	2.08	0.53	1								1									
(1) OWL Lite		2.08	0.53		1	1															

VI. CONCLUSION

Semantic concepts, technologies and trends are researched and analyzed in this study. Semantic web concepts are provided for researchers interested in semantic web and semantic search. In addition, applications of semantic web and applicability of semantic web is interrogated to open new horizon to relevant researchers. As a result, with regards to applicability, some trends are inferred.

The results show that data integration is decreasing but it is still the most popular context type. Instead the improved search have a tendency to increase. They are interchanged, and the situation confirms the evaluation of web discussed above. Social networks declines but another impact appears as portal.

The most important applied area is still institutional. It can be consider that institutional framework pioneers the semantic applications. On the other hand, variety of applied areas increases day by day.

Developers still prefer RDF(S) technology because of its performance. It can be deduced that developers desire maximum performance against their effort.

Although it is not considered in this review it might be worth to make similar review on multimedia application on semantic web. Since semantic studies on multimedia are also drawing attention by researchers.

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