Navigating and Browsing Linked Open Data: State-of-the-Art

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Abstract: Data race is the phenomena of conversion of web of text to web of data; Linked Data provides uniform platform and infrastructure for the organization of structured data from diverse domains on the web. RDF, HTTP and URIs are the primary source of publishing structured data on the web linked between different entities and data sources. Subsequent formation of this large linked data cloud, besides numerous advantages and applications, results in many challenges in navigation, discovery, interactivity, visualization and usability to end users. Linked Open Data (LOD) Browsers provide generic interfaces for exploring, navigating, analyzing and visualizing the different data sets connected in open data cloud. These browsers aim to explore, navigate and visualize large cluster of web of data. This paper aims to present state of the art in Linked Open Data browsers. The paper will help out those researchers and industrial scientist who are planning for designing advanced interfaces for browsing and navigating Linked Open Data.
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1. Introduction

Linked Data [1, 2] are set of best practices for publishing and interlinking structured data on the web introduced by Tim Berner-Lee, knows as Linked Data principles. The basic idea of Linked Data is to apply the general architecture of the World Wide Web to the task of sharing structured data on a global scale. These techniques provide a uniform platform and infrastructure for organization of structured data from diverse domains like people, companies, publications, videos and music, social data etc. This web infrastructure opens a new era of applications for different operations of mining of data from connecting sources, like traditional way of web surfing, Browsers are needed to surf the web data. Uniform Resource Identifiers (URIs), the Resource Description Framework (RDF) and the Hypertext Transfer Protocol (HTTP) are used to publish structured data on the web linked between different entities and data sources which that lead to Single global data space of Web Data [1].

Figure 1 illustrates evaluation of linked data starting from web of documents to web of data. Linked Open Data (LOD) aims bootstrapping semantic web through publishing dataset using RDF, following the rules for publishing and interlinking dataset on linked data cloud. The goal of the W3C SWEO Linking Open Data community project[2] is to extend the Web with a data commons by publishing various open data sets as RDF on the Web and by setting RDF links between data items from different data sources.

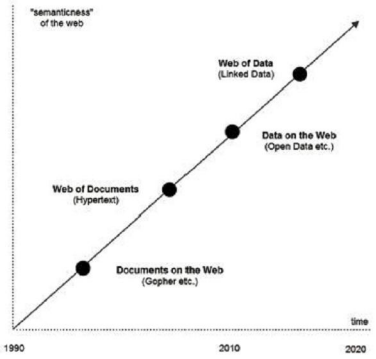

Figure 1: Evaluation of Linked Data

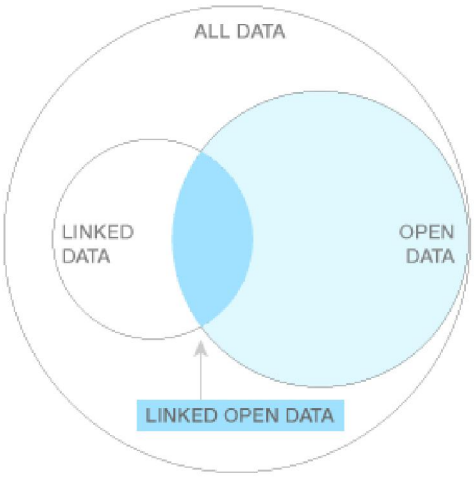

Figure 2: Liked Open Data

Figure 2 illustrates difference between open data, and liked data, the merger of both linked data

and open data results linked open data. The web of linked data [3] provides large, interlinked network of information fragments contain a huge dataset from various data providers. The web of text switched to the web of data, this race of data is known as data race. Organizations from commercial and non-commercial are putting hard to publish their data and format in machine-readable format called Resource Description Framework (RDF), data further enriched by ontologies with well-structured defined semantics, thus Application has good chance of reusing, integrating, and reasoning with data for providing more effective services. However the users are only aware of only a small portion of URI as starting searching session or small collection of entries depending upon the type of user. Starting from these entry points, the web need to be explored to reason queries and retrieve required result set. However discovering in this large information space it-self gives many challenges in the area of navigation, discovery, interactivity, visualization and usability to the end user. Specialized RDF/Semantic browsers are used to navigate among different RDF Resources. These applications attempts to provide data source representation in variety of ways in term of usability. Linked Data browsers are generic interfaces for exploring, navigating, analyzing and visualizing dataset connecting in open data cloud. Browser for LOD highlights information with respect to different knowledge aspects hidden in linked data. LOD Browser appears as hosted application or browser extensions. This Paper aims to focus on different LOD browsers and comparative analysis of LOD browsers used for different operation related to Linked open data and linked data cloud navigation and visualization.

The paper is organized as follow: Section II presented Introduction and Motivation of Linked Data browsers, section III describes Need Assessment for LOD browsers, framework for evaluation of LOD browsers, Section IV reflects description of existing LOD Browsers, Section V presented comparison of LOD browser on the basis of framework in Section IV, challenges of LOD Browsers and recommendations and conclusion are also part of the paper discussed in VI.

Key contributions of this paper include:

- The key contribution is the study and review of LOD Browsers and its state-of-the-art
- User and machine oriented challenges are identified for future design aspects of LOD Browsers
- A comprehensive outlook on emergence of LOD Browsers in area of linked Open Data, comparative analysis of LOD browser with leading trends in markets is highlighted.
- A number of recommendations are highlighted to serve as new dimensions for the researchers in this domain.

2. Background and Motivation

The Web of Data or Linked Open data are set of best practices for employing publishing structured data on the web and their connections/linkage between different data sources using Resource Description Framework (RDF) and Hyper Text Transfer Protocol (HTTP). Linked Data Principals [3] are known rules for publishing on linked open data. Web of data can be overlaid as additional layer on traditional web, based on the following features.

- Generic Data and may contain any type/nature of data
- Anyone can published/use data
- Data publisher have no limitation/constraints in use of vocabularies
- RDF Links are primary source of connection among entities.

W3C Semantic Web Education and Outreach Group[4] has established to developed strategies and awareness among web community regarding benefits and of semantic web and its related technologies. Linked Open data is initiated by this group. This Project aims to identify the existing and ongoing dataset available under open licenses, converting and publishing on Linked open data cloud with help of linked data principle. The growth in the project was mainly due to open nature of project, where anyone from anywhere can participate by publishing dataset according to linked data principles. Linked Data Cloud Diagram [5] visualized datasets in LOD clouds and node to node inter-linkage relationships. Each node represents district dataset published as data set as linked data. RDF links are represented in the form of Arch; normally arcs correspond to greater number of links between two datasets, bidirectional arcs indicates outward links to other existing dataset.

Each node in this cloud diagram represents a distinct data set published as Linked Data. The arcs indicate that RDF links exist between items in the two connected data sets. Heavier arcs roughly correspond to a greater number of links between two data sets, while bi-directional arcs indicate the outward links to the other exist in each data set.

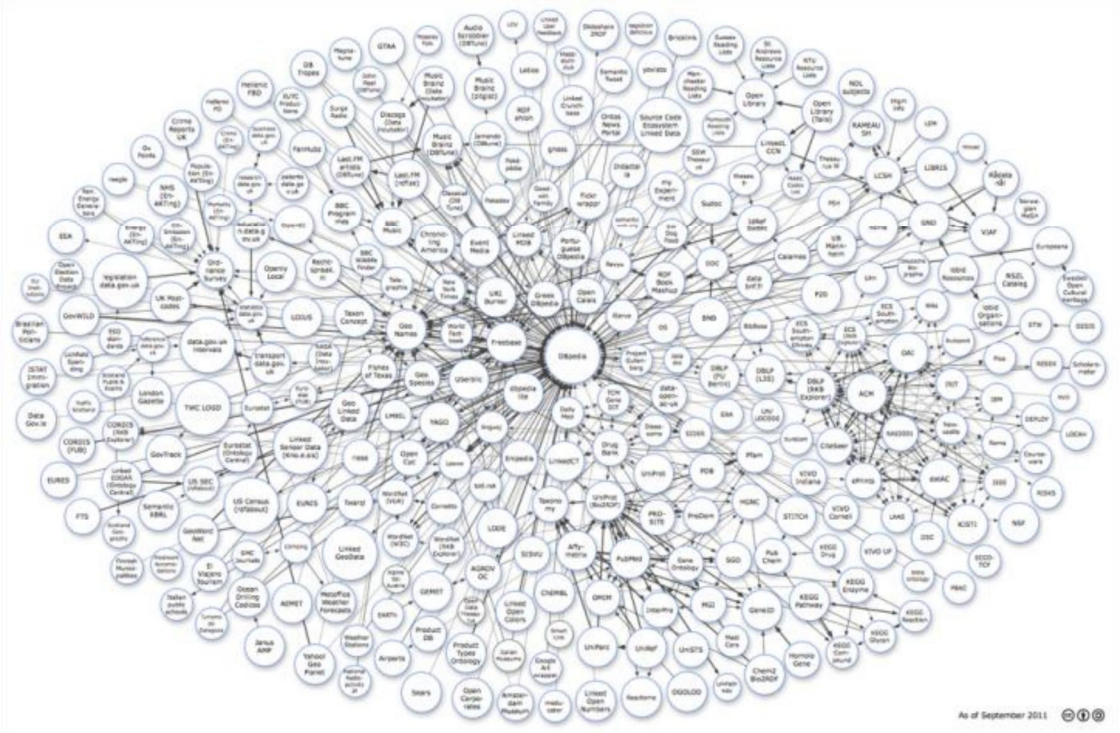

Figure 3: Linked Open Data Cloud [5]

2.1 Linked Open Data Cloud Trends and Statistics [5]

A number of dataset have been published in linked open data cloud on the principles of linked data. Individual and organization well contributed in this open cloud. As of August 2011, out of the 295 datasets in the LOD cloud 113 (38.57 %) are published by the data producers themselves, while 180 (61.43 %) are published by the third-parties. Linked Data technologies are being used to share data covering a wide range of different domains as illustrated in Table 1that presents domain wise distribution with their corresponding number of dataset available, RDF links and number of triples. Figure 4 illustrates domain wise distribution of triples while Figure 5 present domain wise distribution of RDF links across the LOD cloud.

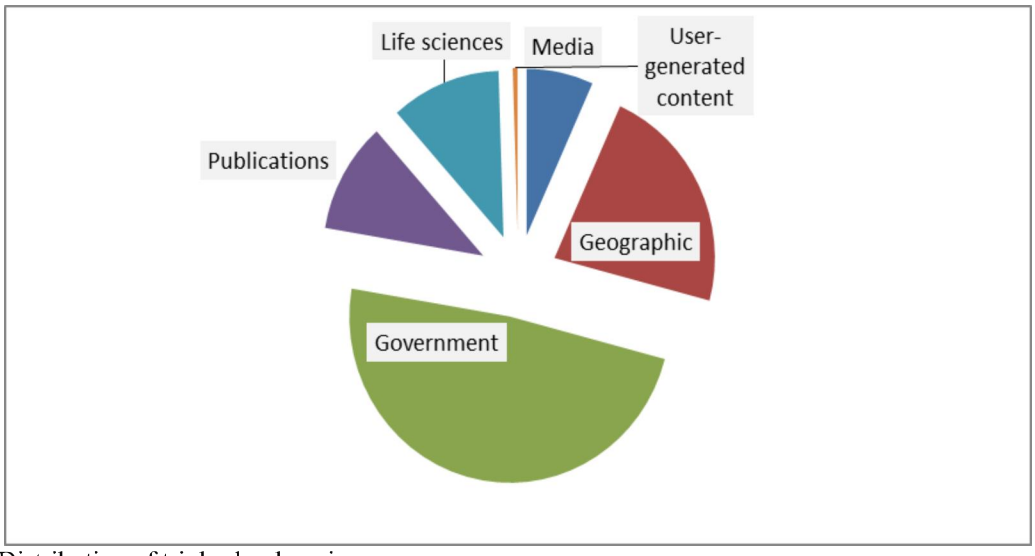

Figure 4: Distribution of triples by domain

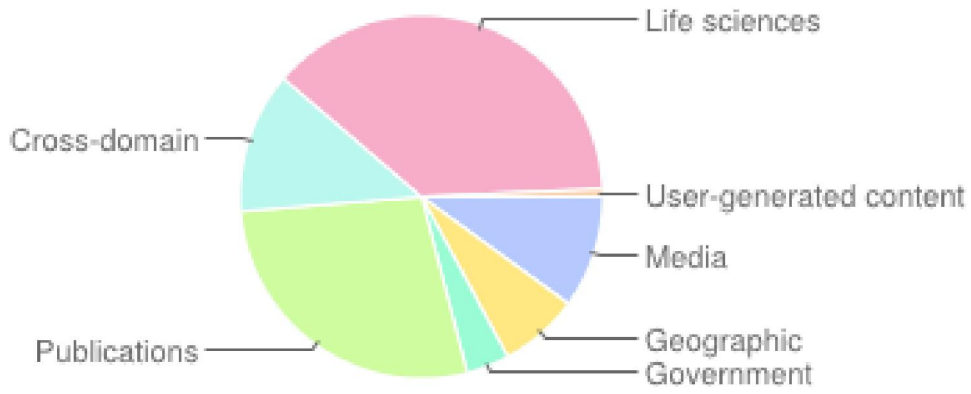

Figure. 5. Domain wise distribution of RDF links[5]

Table 1: Quantity of triples and the quantity of RDF links per domain

Domain Name	Number of Datasets	Number of Triples	Number of Triples (%)	Number of RDF Links	Number of RDF Links (%)
Media	25	1,841,852,061	5.82 %	50,440,705	10.01 %
Geographic	31	6,145,532,484	19.43 %	35,812,328	7.11 %
Government	49	13,315,009,400	42.09 %	19,343,519	3.84 %
Publications	87	2,950,720,693	9.33 %	139,925,218	27.76 %
Cross-domain	41	4,184,635,715	13.23 %	63,183,065	12.54 %
Life sciences	41	3,036,336,004	9.60 %	191,844,090	38.06 %
User-generated content	20	134,127,413	0.42 %	3,449,143	0.68 %
Total	295	31,634,213,770	100%	503,998,829	100%

Data published by data provider and third party contribution in central cloud are out of the 295 datasets in the LOD cloud 113 (38.57 %) are published by the data producers and 180 (61.43 %) are published by third-parties. In order to make it as easy for cross applications to access and process Linked Data, data providers should publish data according to a set of best practices, HTTP and standardized Web formats i.e RDF/XML, RDFa, XML and GRDL. Table 2 shows the categorization of LOD cloud datasets using absolute number of outgoing RDF links. Table 3 illustrates the classification of LOD cloud datasets which are target of the outgoing RDF links of the other datasets. Table 2and presented Linked Data categorization using absolute number of outgoing RDF links from Linked Open data cloud while

Table 2: LOD datasets categorization using the absolute number of outgoing RDF links [5]

(Out-)Links	Number of Datasets
up to 1,000	30 (10.17 %)
up to 1,000	90 (30.51 %)
1,000 to 10,000	58 (19.66 %)
10,000 to 100,000	45 (15.25 %)
100,000 to 1,000,000	43 (14.58 %)
more than 1,000,000	29 (9.83 %)

Table 3: LOD datasets absolute number of outgoing RDF links of other datasets in the cloud [5]

Number of Linked Datasets	Number of Datasets
more than 10	27 (9.15 %)
6 to 10	17 (5.76 %)
5	5 (1.69 %)
4	19 (6.44 %)
3	38 (12.88 %)
2	62 (21.02 %)
1	98 (33.22 %)

To understand linked data applications, linked data provider should use terms form deployed vocabularies to represent data. Majorly all data sources use terms from the W3C base-vocabularies RDF, RDF Schema, and OWL. In addition to 191 (64.75 %) of the 295 data sources in the LOD cloud use terms from other non-proprietary vocabularies. Altogether 201 (68.14 %) out of the 295 data sources provide a SPARQL endpoint. 117 (39.66 %) out of the 295 data sources provide RDF dumps.

3. LOD Browsers Framework

RDF links enables users to navigate from different dataset within same data source, following the directions the Linked data browser are developed with aim of exploring/navigation, analyzing, visualizing of Linked Open data. With the growing popularity of web linked open data, now it is grown

up to staging size of 38.5 billion triples in the central cloud of open data. The proportional increase in the dataset will be evidenced with the ubiquity of mobile devices and production of low cost sensors, which is accessing this cloud of information for various purposes.

3.1 Classification of Human Oriented Users for LOD

The utilization of web of data mainly depends on the useable interfacing, browsering and visualization for all type of users. Ben [6] classified users into three types, these can utilize the full potential of Linked Open data.

3.1.1 Lay User

These types of users don't have or having very basic understanding of semantic web technologies used behind the interlinking of datasets, such users utilize Linked Data browsers for exploring large dataset or area of general interest. Lay users normally span the categories of novice to causal users; they may be interested in data they explore.

3.1.2 Technical User

These user having expert level understanding of Semantic web and Linked data, they might use browsers for data retrieval, integration, analysis; advance filtering and querying.

3.1.3 Domain User

These user have expertise in specific domain knowledge, however it is not necessary that these user should have good understand of semantic web and linked data technologies as like Technical users. This type of user utilize browser for advance querying and filtering in domain specific queries and reasoning. They have very good understanding of data structure and content in their domain and bring this knowledge to guide both knowledge discovery and direct information retrieval.Other than user understanding of domain and technical knowledge about linked open data; there are several challenges for designing usable browsing and visualization tools for browsing data of Linked Open Data.

Frameworks for Evaluation of LOD Browsers

The general evaluation indicators adopted from [7] [8] are used to compare different LOD browsers are as follow

Indicator guidelines	
Data Conversion	LOD Browser capability to convert data from one format to another format, support for Link data and non-liked data formats, conversion to HTML, HTML to LOD conversion, majorly this include conversion from unstructured to structure data to RDF and other format like XML, JSON and RDF/XML format.
5-Star Schema	Berners-Lee[3] suggested 5-Star Schema for Linked Open data, every star from one to five having enhanced semantics, **Star-I** is data available on web whatever format it is, **Star-II**, machine readable data available n the web mostly in form of Tables and Microsoft Excel File, **Star III**, contain start II but also with some non-property format like CSV, **Start IV**, contain those data which contain the above stars plus with use of open standards of W3C like RDF and SPAQL and finally **Star V**, which include all the above stars plus outgoing links to other people data to provide context. This indicator will facilitate us about the level of data consummation support by particular browsers.
Data overview	Global data overview, useful for over view of data structure, global linked data source and local linked dataset support
Presentation	The use of visual elements like graphics, images and other graphical user interface elements which can enhance the perception to understand a huge cloud of data in highly intuitive way. This might be benefit more for layuser who have very basic understanding of underline technologies
Detail on demand	As Linked Open Data connected via RDF URIs, however depth of linkage and details need to be supported by browsers, this can be used for deeper analysis of data
Scalability Support	Browser should be scalable enough to accommodate and manage large, complex, cross linked, interlinked data store in remote locations.
Querying	Support formal query syntax such as SPARQL targeted to tech- users, in addition to more intuitive search feature like keyword and keyword-in-context or question- answering in a forms-based UI, or visual point-and-click UIs, that better support lay-users
Filtering	Highlighting more relevant information on front and suppressing less relevant information. Visually dynamic filters additionally provide in a simple, intuitive method of querying, which allow previewing of more structured, formal queries
Presentation templates	Pre define structures or design template that map data or features to standard (visual) representation
Entry point	Entry point to Linked data browsers are either URI or keyword or direct manipulation especially for tech user and lay user
Non-domain specific	Generic browsers from which users can begin exploration and information retrieval, over the very wide range of LD currently available
Publication	Support for publishing new data into Linked data and method for highlighting error and validating new data and links to existing linked data
Edit underlying data	Enable end users to enrich existing data with new annotations and other metadata, and correct errors
Data Reuse	Encoding output using standard ontologies and vocabularies, ensuring reuse
Navigation	Navigation among different RDF resource in forward and backward.
Plug in for HTTP Browsers	Either there are any supported plug-ins for traditional web browsers

4. Description of Existing Linked Open Data Browsers

Dadzi and Rowe [8] presented recent survey on current approaches and visualizing Linked data browsers, they classified the browsers into two types I) Text base browser or text-based representation II) Graphical representation, other type of browses are faceted browsers

4.1 Text-based Browsers or Data browsers

These browsers use textual structures of Linked data such as tables, lists to present entity, property and relationships. This includes tools that use presentation template that resolve literals more human readable, text-based layout. Faceted browsing feature is also available in some browsers. Examples of such browsers are Dipper, Disco, Marbles, Sig.ma, URIburner and Zitgist.

4.1.1 Disco Hyper Browser

Disco – Hyper Browser[9] is an open source browser for navigating the Semantic Web as an unbound set of data sources, this browser render all information from a semantic web resource in the form of HTML pages. Navigating between different RDF resource links, the browser dynamically retrieves information by dereferencing HTTP URIs and by following *rdfs: seeAlso* links. All processing occur on the server and result presented to client, the output is displayed in the form of table of property-value pairs, specifying the source returned. Disco Browser is deployed on presentation layer of on top of the Semantic Web Client Library [10]; Semantic Web Client Library represents the complete Semantic Web as a single RDF graph with SPARQL. The Semantic Web Client Library observes all data that has published according to the rules above as a single, global set of Named Graphs; the Semantic web client library is multithreaded to allow fast retrieval. Disco allows only for searching and browsing through the Semantic Web however information returned can't be edited.

4.1.2 Marble

Marbles[11] is an open source server-side application that formats Semantic Web content for XHTML clients using Fresnel lenses and formats, Fresnel [12] is browser-independent vocabulary for specifying how RDF graphs are presented. Colored dots are used to correlate the origin of displayed data with a list of data sources; these different colors dots are called Marbles. All formatting, data retrieval and data storage activities are performed at server side by querying the Semantic Web Index Sindice – Semantic Search Engine [13]. Marble also result in the form property-value pair. It also provide SPARQ end point, and can be installed locally, allowing information to be saved in local stores and can be retrieved from local stores. Marble follows known predicates (*owl:sameAs, rdfs:seeAlso*) to obtain more information and human-friendly labels.

4.1.3 Sig.ma

Sig.ma[14] – Semantic Information Mash-up [14] views "web of data as information space", this browser integrate Linked data from multiple sources allowing data navigation. This browser is much favorite for lay user as the initial interaction start with keyword search unlike the other browser that start exploration of web data with URI. However the Option of starting search with URI is also available feature. It is build-in on the top Sindice Semantic Search engine. Results are presented as recordable list of verified sources, end user gets benefited from the option of relevance which may be accepted or rejected by the end user.

4.1.4 URI Burner

This browsing service delivered structured data about web resources, generating an RDF Graph of resources, using existing well-known ontologies. It take a web URI and represent the dereference resource RDF[15]. It also provides a Firefox extension which can be used to bookmark the URIs of Interest. The result is presented in the form of property-value pairs, the requested input can be started from free text search and for looking up URI from a text label. A SPARQL query end points is available, additional feature of extracting Linked data to Raw RDF as XML and other version of n3 and turtle is available for application developers

4.2 Browser with Visualization Options

These browsers use primary visual and graphical structure i.e. images, maps, graphs and timelines to represent linked data. Examples of such browser are OpenLinked Data browser, Tabulator, Lena, Ontology OLD and Fenfire.

4.2.1 Open Linked Data Explorer

Open Linked Data Explorer[16] (ODE) is web based RDF data browser for interacting Linked Data. ODE requires a URI as input or text string by which it will locate resource URI, ODE attempts to extract metadata to an RDF representation and display results. Various views are available i.e. What, where, When, Who, Images, Grid view, Tag Cloud, SVG Graph, Navigator, Custom. Filters may be applied by selecting different data attribute in the result returned. The iSPARQL may be used to save to reuse the ODE query. Firefox extension is also available for public entry point.

4.2.2 Tabulator

Tabulator[17] is an Open source generic RDF data browser which treats Semantic web as connected RDF graph for exploring all RDF data in outline and table modes. It uses globally referenced concepts (FOAF) to interpret the content of Linked data. Tabulator supports for presenting the content of

linked data resource to end users via an easy interface to configure and run. Users click through tree structure of text labels to display increasing level of refinement. Queries are stored and can be reloaded as required. A Firefox extension is also available.

4.2.3 Lena – RDF / Linked Data Browser

LENA[18] stands for lens-based navigator and has been developed within the research project XMedia to support users dealing with complex data from the automotive and aviation industry. LENA supports i) the visualization of RDF data in a human-readable way, based on ii) the description of complex data selections, and iii) the provision of multiple renderings for the same data to conform to the specific information needs of different LENA Lens based Navigator. A lens represents a particular view onto RDF data and is described by the Fresnel Display Vocabulary. LENA supports the use of multiple lenses and indicates if they are available for a resource. To write lenses for complex RDF structures created through sophisticated ontology frameworks like COMM or X-COSIM, LENA supports SPARQL selectors. As comprehensive query language for RDF, SPARQL complies the requirements needed to select from these complex structured RDF graphs.

4.3.4 Ontology Browser

Ontology Browser[19] allows you to navigate around OWL ontologies and Linked Open Data online. Ontology browser surf OWL ontologies and/or RDF Linked Open Data together in one interface, fully indexed and linked content, split down by module and entity type. It supports images, sounds and locations, DL queries using full Manchester Syntax with auto completion and parsing. Supports permalinking for sharing pages with friends and community

4.3 Browser with Faceted Browser options

Faceted browser as an alternative way of exploring data compared to the traditional methods of text match searching and browsing through the results sequentially on choice after closer choice. A faceted browser offers a perceptive interface that allows the search results to be grouped into facets which, when selected, Narrow the search results to show only the items that share the attributes of that particular facet.

4.3.1 Sparallax

Sparallax[20] is a faceted browsing interface for SPARQL endpoints, based on Freebase Parallax. The faceted browser allows queries to be easily generated over different end-points, utilizing the Linked part of Linked Data. The easy to use interface allows someone with no knowledge of Linked Data or the Semantic Web to use these technologies. However, Sparallax is restricted as only Virtuoso SPARQL end-points are supported and all properties should explicitly specify their range and domain which limits the usability of this tool. Sparallax can also become rather slow the more complex a query becomes.

4.3.2 /Facets

Facets[20] is an open source faceted browser for RDF data. /Facets uses RDF files which are designed to handle any RDF schema making up for the limitations of Sparallax. /Facets also allow users to use Linked Data without needing to know any of the underlying principles involved. /Facets slow down query as the query gets more complicated and advance in nature.

5. Comparison of LOD Browser

The analysis is based on indicator opt in section III i.e. Navigation, Presentation, Target Users, Schema Star, linking and faceted browsing, the various browser are analyzed in Table I on basis of indicators mentioned in section III of the framework. Linked Data Browsers are generic interfaces for navigating, retrieval, editing, and presentation of RDF resource in Linked Open Data. Powerful LOD browser need to be developed for exploration of huge amount of dataset available openly for all three types of target users. Various indicators of scalability, pluggable architectures should be kept in mind while designing new browser infrastructures or plugging with existing web browsers. The browser should facilitate lay user and domain experts in better way, some basic features of presentation, navigation, retrievals, storing, cashing, faceted, format and manipulation of returned result sets, Views of result set in form of HTML, tree, table, timeline, graph structures, etc. The overall study was focused on overview major LOD browsers available along with their advance features, analyzed multiple features, Marble, ODE browser which are mainly text oriented browser yielded power full resulted however Fenfire browsers power much lies in their visualization and data manipulation, the future browser should be highly interactive with faceted browsing, must solved navigational challenges and most of all data discovery challenge, fetching data from diverse dataset across structure and unstructured datasets.

6. Challenges of LOD Browsers

The web of data connect huge data from the real world domains and other web Resource, how a browser will present this huge range of data to the user in well presentable and highly interactive format, and resource linkage between real world domain dataset and general web data, these are few challenges of LOD Browsers as identified in [7, 8] are as fellow.

Indicators	Dipper[21]	Disco [9]	Marble [11]	Sig.ma[14]	URIburner [15]	Fenfire[22]	Tabulator [17]	ODE[16]	Sparallax[20]	Factes[20]
Visual presentation	-	-	-	-	-	X	X	X	-	-
RDF graph view	-	-	-	-	-	X	-	X	-	-
Visual overview	-	-	-	-	-	-	-	-	-	-
Data overview	-	-	-	-	-	-	-		-	-
Detail on demand	-	-	-	-	-	X	X	X	-	-
Highlight links in data	-	-	X	-	-	X	X	X	-	-
Support for scalability	-	-	-	X	-	X	-	X	-	-
Query (formal syntax)	-	-	X	-	-	-	X	X	-	-
Query (forms / keyword)	-	-	-	-	X	-	X	X	-	-
Filtering	-	-	-	X	-	X	-	X	-	-
History	-	-	-	X	-	-	X	X	-	-
Presentation Templates	X	-	X	X	-	-	-	X	-	-
Keyword / entry point	-	-	-	X	X	-	-	X	-	-
Non-domain specific	-	X	X	X	X	X	X	X	-	-
Faceted Search / Browse	-	-	-	-	-	-	-	-	X	X
Edit underlying data	-	X	-	-	-	X	X	-	-	-
Reusable output	X	-	-	X	X	X	-	-	-	-
Target Users										
Target – Lay-users	-	-	-	-	-	X	-	X	-	-
Target – Tech-users	X	X	X	X	X	X	X	X	-	-
5 Star Data Schema										
Produce 5 Star	-	-	-	5	5	-	5	5	-	-
Consume 5 Star	5	4	5	5	5	4	5	5	-	-
Plug In available										
Facets view	-	-	-	X	-	-	-	X	X	X
Navigation										
Forward Navigation	-	X	X	-	X	-	X	X	-	-
Backward Navigation	-	X	X	-	X	-	X	X	-	-
Export RDF / JSON	X	-	-	X	X	-	-	X	-	-
Navigating Global Linked Data	-	-	X	X	X	X	X	X	-	-
Navigating Local Linked Data	X	-	X	X	X	X	X	X	-	-

6.1 Navigation

Navigation of document is one the important feature supported by a browser. The navigation technique is quite different in Linked open data as compare to the traditional web browsing, traditional browser use un-typed links to surf between different pages, while LOD browser used typed links to navigate between different RDF resources in the form URIs. The major challenge is that how browser will respond to allow for forward and backward navigation techniques to the users with support of context navigation [23].

6.2 Interactivity

The utilization of Linked Open data cloud is mainly lies in his interactive feature of sub selection and faceted browsing. However achieving highly user interaction feature is difficult due to use of different languages of the Semantic Web, RDF, OWL and SPAQL. The Challenge above is both user oriented and technology oriented shows substantial gaps in bringing the Linked Open Data to the Human users. Considerable research is devoted to develop such browsers which can facilitated user in finding information in huge data sets of linked open data and to reduce cognitive load on the users.

6.3 Updating of Fresh datasets

Linked open data developed in over last years with rapid growth, new dataset published and old dataset removed [24]. Updation of individual resources need small change, however if data source's infrastructure organized the change will be huge. Updation of frequently used data i.e. weather, traffic etc. is still a challenging objective for linked open data.

6.4 Temporal and Sensor Data – Missing Meta Data

Stream data source are hot area of data publishing now a days, this include sensors data mainly such as GPS, blood pressure, Heart rate etc. These information are critical and having important role in our life. Integration of such type of data is very beneficial for linked data cloud consumers. However due to lake of meta-data in sensors, the integration will be challenge and difficult to defuse such nature of data. Moreover sensor data are

temporal in nature and highly dynamic; integration of sensor data is still a big challenge in linked open data.

6.5 Trust, Spamming and Privacy

Data quality assurance and spam detection is big challenge in traditional web as well as in linked open data. The information published on the cloud is not fully trusted in-term of true information or fake information. Privacy remain open concern in such open cloud environments, it's not only challenging but also dangerous for personal security as well.

6.6 False Links and broken links

Link generation are made available through an automated approach, due to huge size false link also created which are very hard to identify in huge cloud of web of data. Existence of broken links in the LOD cloud is due to missing or incorrect information in underlay dataset. Identification of such missing structure is very difficult in LOD Browsers

7. Conclusion and Recommendations

After a comprehensive survey we come up with number of recommendations which need immediate attention from research community as well as the industry to build up infrastructure for the underlying technology:

- Heterogeneous technologies are used for formulation of LOD cloud; data representation issue can be solved with help of using semantic web technologies, adoption of standard ontologies can be used for translation and encoding data.
- A Picture worth thousand words, visualization truly facilitated all domain users the ability to foster insides and understanding of data. Effective knowledge discovery and analytical activities are much desirable for browser to present to users of LOD.
- Browser should be made more interactive and can be used for visualization and analytical purpose as well
- Need of specialized Development toolkits for plug-ins and browser development for LOD Centric production and consummation
- Reasoning engine may be integrated to LOD Browser for effective Reasoning of LOD Cloud for vast exploring of huge datasets
- Excellent visualization tools are need to be developed to analyze and visualized congested Layers information in highly interactive way.
- Extended LOD Browsers should be design which can serve as Plug-in or component in exciting mobile / web browser, existing mobile/web clients should act as LOD client without use of specific browser components for LOD Experience.
- Extensive standards should be developed for interoperability between data sharing across various LOD Browsers.
- Protection mechanism for user personal information and private data should be addressed that will aims to enhance user trust on linked open data
- Common data structure might be developed across all LOD browsers for content sharing and reuse. key value and format for matching markers to another resource liked and data structure of basic/detailed information related to each object

Linked open data browsers are generic interfaces for exploring huge data sets represented from different domain area in single cloud. Text based and visualized optioned browser are available for exploring of LOD Cloud for variety of purposes, however, there is need of specialized interfaces that plug-in to existing traditional web browser or mobile browser. The overall study has focused on major available LOD browsers along with their advanced features, analyzing their various features. The future LOD browser should be highly interactive with faceted browsing ability, should address issues of navigational challenges and most importantly all data discovery challenge, the ability of fetching data from diverse dataset across structured and unstructured datasets. This study will surely help to bridge the gap between machine-oriented LOD and its human users.

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