Ontology Libraries: A Study from an Ontofier and an Ontologist Perspectives

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Abstract. Similar to the idea of a digital library, in the recent time, a new concept has emerged called an ontology library. Principally both a digital library and an ontology library have the similar kind of purposes and objectives to achieve (e.g., store, organize and provide access to the digital objects), except the kind of materials they deal with. Similar to any other digital content, ontology construction is a time-consuming and costly affair. It is important to organize and preserve ontologies in a manner that they are easily searchable, identifiable, selectable, shareable and reusable. An ontology library is a kind of organizational network that is easily accessible from any place or location and offers relevant or admissible ontologies in a well-organized manner and with a competent approach, which is based on different well-established ontology representation languages, such as RDFS, OWL, etc. The objective of this paper is to disseminate the result of our survey research conducted based on some of the existing ontology libraries. We envision that the result of this study will help the future ontology library developers to plan the design of libraries to overcome the increasing complexity in ontology search and retrieval.

Keywords: Ontology library, ontology repository, ontology directory, ontology registry, evaluation, survey study.

1. Introduction

Similar to the idea of a digital library (Chowdhury and Chowdhury, 2002), in the recent time, a new concept has emerged called an ontology library. Principally both a digital library and an ontology library have the similar kinds of purposes and objectives to achieve (e.g., store, organize and provide access to the digital objects), except the kind of materials they deal with. While a digital library deals with the documents of various types, such as text, audio, video, images, etc., an ontology library deals with the ontologies (where an ontology is an intelligent object, often referred as a digital artifact, consisted of representations of the entities in terms of their types, properties and the relationships of a domain of discourse (Gruber, 1993; Dutta, 2014)).

An ontology library is a kind of organizational network that is easily accessible from any place or location and offers relevant or admissible ontologies in a well-organized manner and with a competent approach, which is based on different well-established ontology representation languages, such as RDFS, OWL, etc. (Noy et al., 2008). The goal of an ontology library is of two-fold: (i) to provide a platform to the ontologists (a practitioner who builds the ontologies) to publish, store, preserve, share and evaluate the ontologies; (ii) to facilitate the ontofiers (an ontology user) to retrieve the right ontology at the right time to make the best (re)use of it.

Besides the term ontology library, we often come across with some other related terminologies, such as *ontology repository*, *ontology registry*, and *ontology directory*. Conceptually they are all similar kind of things but still they have some differences. An ontology repository is a collection of the ontologies and their metadata. An ontology registry consists of a list of ontologies and metadata instead of the actual ontologies. It is an architecture that allows ontology providers and users to use, share and exploit semantic information in a real world scenario. An ontology registry offers several tools and technologies which enable the users to find out the relevant ontologies as per their need. An ontology directory is a service which provides metadata and sources of information of the ontologies. Besides providing the reference services, it supports the registration services and service requests (these are further elaborated in section 3).

The objective of the current work is to disseminate the result of our survey research designed based on some of the existing ontology libraries. We envision that the result of this study will help the future ontology library developers to plan the design of libraries to overcome the increasing complexity in ontology search and retrieval. The entire work is carried out as follows: we discuss the various concepts related to an ontology library. We elaborate some of the popular ontology libraries and analyze them from both the theoretical and implementation perspectives. We study them from the technological, structural and infrastructural perspectives. We envision that from the current work the various agencies namely, the ontology researchers, practitioners, and ontology library developers will be highly benefitted.

The rest of the work is organized as follows: section 2 discusses the related works; section 3 provides the fundamental classification of ontology libraries; section 4 discusses some of the existing ontology repositories;

directories and registries. It also illustrates the relationships between the various types and forms of ontology libraries. Section 5 discusses the result of evaluation study by elaborating the parameters that are used for the selection of ontology libraries for this study and also the high-level features that are used to evaluate the libraries. Section 6 concludes the current work discussing the limitations of the present work and the future plan of work.

2. Related Work

Heijst et al. (1995) have discussed the ontology library construction to facilitate the development of medical knowledge based system. They have made a relationship model, which is related to the problem-solving method, ontologies, and domain specific knowledge. They have used GAMES approach, which is based on the epistemological model and computational model. Ding and Fensel (2001) have made a survey of nine ontology libraries and have proposed some important requirements for structuring the ontology library systems. Initially, they have identified the various characteristics (e.g., browsing, searching, editing, versioning, and language) for evaluating the functionalities of ontology library systems and compared the libraries based on them. Finally, they have concluded by proposing the important features for structuring the ontology library systems. Mathieu d'Aquin and Natalya F. Noy (2012) have studied 11 existing ontology libraries on the line of their similarities and distinctions. They have primarily focused on the ''server'' functionalities of the libraries: what is the type of access that they provide? what stages in the ontology life cycle they support? and so forth. The main goal of this study was to identify a set of questions that an ontology practitioner and user should consider in searching ontologies or publishing in them.

In 2013, Zubeida et al. have proposed to solve interoperability issues between the domain ontologies and have also shown the basic steps in the direction with the repository of ontologies for multiple uses. They have mainly focused on various components of ROMULUS ontology repository by comparing with different other repositories (Khan et al., 2013). The paper explains the features of six foundational ontologies along with their mappable and non-mappable elements.

3. Classification of Ontology Libraries

Besides the term ontology library, we often come across with some other related terminologies, such as *ontology repository*, *ontology registry*, and *ontology directory* (Fig. 1). Conceptually all these are similar kind of things but still they have some differences. We discuss them briefly as follows.

3.1 Ontology Repository (OR)

An ontology repository (e.g., BioPortal, AgroPortal) is a facility where ontologies and related information (e.g., ontology metadata including the information on who included the ontologies) are stored, managed and retrieved[1]. The purpose of ontology repository is to enable users to upload, browse, search, share and manage the ontologies. It is necessary for ontology developers to elucidate the characteristics and exchange the ideas of ontology repository in general and specific contexts to the users. Some of the features of an ontology repository are summarized below (d'Aquin and Noy, 2012).

- *Searching and browsing*: are the basic features of an ontology repository. Any ontology repository must have these basic features.
- *Storage and preservation*: are the other two most important and common features of an ontology repository. Generally speaking, an ontology repository captures and stores ontologies in different formats into a database server.
- *Retrieval of ontologies*: plays an important role in amalgamating with other ontologies, to develop a new ontology and also to use in domain application.
- *Support for the management of ontologies*: this feature of an ontology library enables the users to keep track of ontology versions, creation date, etc. For the excellence of ontology management, the use of ontology metadata is a necessity (Dutta, Nandini and Shahi, 2015).
- *Standardization*: an ontology repository follows some standardization to represent existing ontologies through various language formats and taxonomical structure of ontologies.
- *Mapping*: is another core feature of an ontology repository which provides an access to a conceptual data model. It also gives access to search and downloads the branch of ontologies.

[1] http://ontologforum.org/index.php/OpenOntologyRepository_Scope

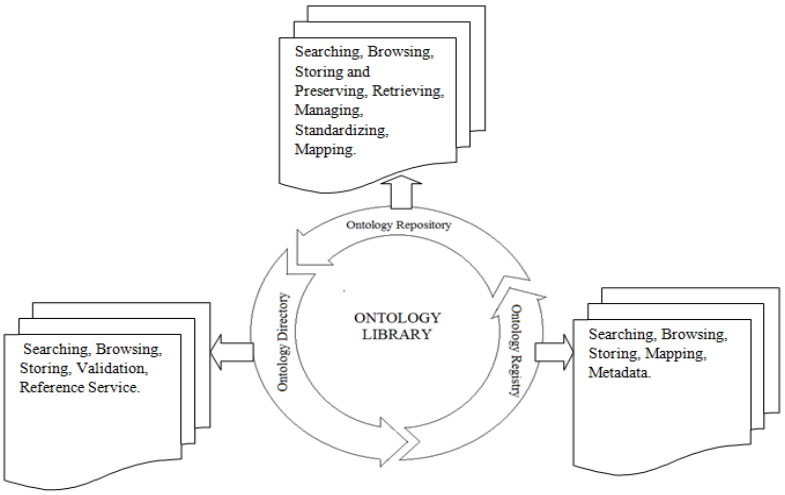

Fig. 1. Different Categories of Ontology Library

3.2 Ontology Directory (OD)

Ontology directory is a service that provides the information about ontologies that are available in a particular platform. Ontology directory contains the reference to the definition of ontology related language based schema such as OWL, XML, and RDF Schema (Tudorache et al., 2006). It provides metadata and source of information. Ontology directories are clearly more significant in the same domain related ontologies (e.g. ODP). Ontology directories include crawlers to search well-formed ontologies on the Web.

Ontology directories simply caters the reference ontologies in a particular domain (e.g., e-Government). Normally it follows simple hierarchical structures, which is effective in data storage and classification. An ontology directory can be referred as a service framework where registration service and service request are provided to the users (Li et al., 2009).

Some of the significant features of an ontology directory are:

- *Search*: an ontology directory provides search facility within the directory, same as in ontology repository and ontology registry (discussed later).
- *Browsing*: ontology directories apart from the search facility, an ontology directory enables different web application to access servers, so that users can browse easily and efficiently.
- *Storing*: display the total number of ontologies stored in the server.
- *Validation*: an ontology directory, ontologies are submitted by unregistered users, registered users and administrators, but validation is done by both committee members and registered users and some of the directory has a strong automatic validation facility.
- *Reference service*: most of the ontology directory has reference service which assists to the user with their issues.

3.3 Ontology Registry (OReg.)

A registry provides a data storage interface where data, knowledge, metadata of a semantic object including the name of the person or any community and process of using data are registered. It can be defined as a platform where a list of metadata can be declared for visualizing data, storing information and access the knowledge about the domain, scientific elements (Stock et al., 2010). An ontology registry (e.g., MMI-ORR) consists of a list of ontologies and metadata instead of consisting the actual set of ontologies. An ontology registry can be expressed as a combination of URIs + Registry + RDF.

Some of the basic key features of an ontology registry are:

- *Search facility*: is the key feature of an ontology registry.
- *Browsing*: is not an essential feature of an ontology registry. However, some of the registries provide users with browsing facility for accessing ontologies within the registry.
- *Storage*: is an another feature of an ontology registry facilitates in storing the metadata and knowledge about a semantic object including the author information and licensing.
- *Mapping*: facilitates the users in creating, storing and creating the mapping between ontologies.

- *Metadata*: it is an essential feature of an ontology registry. It enables in capturing the data for each original, modularized, mapped and merged ontologies (Khan et al., 2013).

4. Some of the significant ontology libraries

The three types of ontology libraries, namely, ontology repository, ontology directory, and ontology registry do not only limited to domain ontologies, but they also contain general purpose (a.k.a. foundational) ontologies and mixed ontologies. A diagrammatic representation of the various types of ontology libraries and the various forms of ontologies is provided in Figure 2. In the figure, by domain ontology, we mean the ontology that deals with a particular subject (e.g., food ontology, music ontology); by general ontology, we mean the ontology that consisted of generic concepts and do not deal with any particular subject (e.g., DOLCHE[2], SUMO[3]); by mixed ontologies, we mean the ontology libraries that deal with both the domain and general purpose ontologies. Table 1 provides some example of the real-world ontology libraries with the kind of ontologies they deal with. In the following, we briefly discuss some of the real-world libraries.

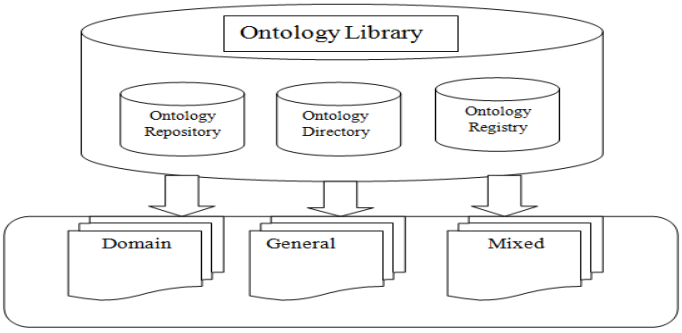

Fig. 2. Different forms of Ontology Libraries

Table 1. Relationship between the various types of real world ontology libraries and the kind of ontologies

Ontology Repository			**Ontology Directory**			**Ontology Registry**		
Domain	General	Mixed	Domain	General	Mixed	Domain	General	Mixed
BioPortal https://bioportal.bioontology.org	COLORE http://stl.mie.utoronto.ca/colore/	ROMULUS http://www.thezfiles.co.za/ROMULUS/	OeGov http://oegov.org/	ODP http://ontologydesignpatterns.org	ONKI http://onki.fi/	MMI-ORR http://mmisw.org/	——	Protégé ontology library http://protegewiki.stanford.edu/wiki/Protege_Ontology_Library
AgroPortal http://agroportal.lirmm.fr/					DAML Ontology Library http://www.daml.org/			

4.1 Ontology Repository

BioPortal: BioPortal is an open registry developed by the National Center for Biomedical Ontology (Mathieu & Natalya, 2012). It contains the biomedical ontologies. The community service of BioPortal assists users with technical requirements by evaluating the ontology content.

Features of BioPortal (d'Aquin and Noy, 2012)

- BioPortal provides an interface to upload and edit ontologies, download the existing ontologies. It also provides access to ontology metadata with content through web service.
- The repository uses special kind of client server component Concurrent Version System (CVS) as part of their infrastructure to import ontologies which are submitted by different registered users.

[2] http://www.loa.istc.cnr.it/old/DOLCE.html
[3] http://www.adampease.org/OP/

- BioPortal follows automatic syntax validation mechanism on submitted ontologies and gatekeeping rules for collecting ontologies in the library.
- BioPortal partially uses Ontology Metadata Vocabulary (OMV) for representing the ontologies.
- BioPortal supports multiple formats such as Open Biomedical Ontologies (OBO) format, Web Ontology Language (OWL), Simple Knowledge Organization System (SKOS) and Unified Medical Language System (UMLS).
- Bioportal provides the browsing facility.
- BioPortal supports the comments on ontologies, concepts and mappings.
- BioPortal provides a search interface to search within and across the ontologies.
- BioPortal provides REST based web service access to get and download the latest version of ontologies, to get the root of all concepts of an ontology, and to get a taxonomy of a given concept.
- A mechanism is called Web of Trust which enables users to specify reviewers from a particular group's (e.g. OBO foundry member).
- The NCBO Resource Index of BioPortal is a key functionality system for ontology based annotation and indexing of biomedical data which enable users to reveal data via ontology terms.

AgroPortal: AgroPortal is a web-based ontology repository for accessing and sharing agronomic and plant ontologies. It provides a "one-stop-shop" for ontologies which is related to agriculture and plant. It contains more than 30 ontologies which come from different groups. Since AgroPortal uses the same NCBO BioPortal infrastructure for accessing agronomic related ontologies, some of the features are similar to BioPortal repository (Jonquet et al., 2015).

Features of AgroPortal[4]

- AgroPortal enables users to create ontology annotation for their own data, search and visualize across all ontology content, metadata storage facilities, store and retrieve mapping between different ontologies.
- AgroPortal allows users to create their own relations between terms in different ontologies. It also provides recommendations for using corpus data of ontologies.
- It facilitates mapping to other portal and external ontologies.
- AgroPortal facilitates multi-relation mappings.
- AgroPortal supports the visualization of a subset of a particular ontology.
- AgroPortal also provide a SPARQL end point query interface.

*COLORE***:** The COLORE (Common Logic Ontology Repository) is an open repository structure of first-order ontologies. It provides a platform for ontology evaluation and integration. It is also a contributor to the Open Ontology Repository (OOR) initiative. COLORS's system architecture is based on CL (Common Logic) which is adopted by Samian Platform[5].

Features of COLORE (Grüninger & Katsumi, 2012)

- COLORE addresses specific instances of some modelling problems and also gives solution on them.
- It allows users to view and download existing ontologies.
- All the ontologies are identified by standardized common logic, which is used for specification of first-order ontologies and knowledge bases.
- In this repository metadata exists within the ontology files.
- It has a relationship with multiple standards which support intractability among manufacturing software systems.
- It provides mapping axioms between one module's lexicon to another module's lexicon[6].

*ROMULUS***:** it is a mixed based ontology repository which has a focus to improve semantic interoperability. It is a machine-processable, modularized, aligned and logic-based ontology repository. The entities are arranged manually and automatically. ROMULUS uses open ontology development environment WebProtégé (Tudorache

[4] http://www.bioontology.org/news/agroportal-beta-web-application-released
[5] https://code.google.com/archive/p/colore/wikis/ColoreSystemArchitecture.wiki
[6] http://stl.mie.utoronto.ca/colore/metadata.html

et al., 2013) to access all mappings. It uses OMV metadata vocabulary to facilitate interoperability with other ontologies.

Features of ROMULUS

- ROMULUS motivates users to view and download the ontologies.
- In this repository, administrators can only submit the ontologies.
- Users can save their ontologies with uniformed CVS file format locally.
- It is subsuming with ONSET (Khan & Keet, 2012) for selecting new OWLized[7] version of foundational ontologies and contains logic based alignments such as Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE) and Suggested Upper Merged Ontology (SUMO).
- It provides OMV metadata module for each original, modularized, mapped and merged ontology.
- ROMULUS uses many representational languages and format such as OWL DL, OWL 2 DL, and OBO etc. to represent the ontologies.
- ROMULUS is based on three main components such as PHP-based web server to execute HTML page, Tomcat server to execute JSP page and MySQL database to store ontology alignment, metadata and selection result (Khan & Keet, 2015).

4.2 Ontology Directory

***OE-GOV*:** oeGOV[8] is an initiative by TopQuadrant for collecting, maintaining and publishing eGovernment OWL ontologies. It uses wordpress[9] web software as a technological architecture to create websites. Currently, oeGov focus on the datasets of U.S. Government agencies, departments, offices and state governments (Mathieu & Natalya, 2012).

Features of OE-GOV (d'Aquin and Noy, 2012)

- oeGov allows users to access the lists of ontologies along with the ontology description, namespace URIs, different formats, and dependencies.
- It facilitates blog through which administrators can post the ontologies and attached the collection in the directory. By this, users can access metadata of the ontologies.
- It helps to interpret data through controlled vocabularies, including geospatial and temporal aspects and also navigate 'author of publication' by publication date.
- oeGOV is made of schemas and several datasets. It allows data aggregation and exchanges through standardized format RDF/OWL.
- oeGov enables users to understand how the political process and policy making align with outcomes and Government accountability for efficiencies and effectiveness (Hodgson, 2009).
- It is connected with agency services through the Federal Enterprise Architecture (FEA)[10].

***ODP (Ontology Design Patterns)*:** ODP[11] is a portal (Mathieu & Natalya, 2012) or ready-made modelling catalogue for creating and maintaining ontologies. This pattern helps to manufacture rich and diligent ontologies with less effort. It is a kind of catalogue which basically focuses on the collection of well documented and tested ODPs including examples from the biological knowledge domain. Ontology Design Patterns has provided a method for rich and rigorous modelling in bio-ontologies. Domain modelling ODPs are more specific in the knowledge domain, as ODPs are common for all ontologies so they can also be used in other domains (Aranguren et al., 2008).

Features of ODP (Mortensen et al., 2012)

- ODP is a kind of catalogue dedicated in order to design pattern which allows user's to share experiences and modeling/design problems.
- ODP describes their collected content in a catalogue format.
- ODP allows the quality committee to approve and reviewing design patterns for the content catalogue. It has a library to generate automatic documentation and to provide rich metadata, including ontology links such as 'extracted from' or 'specialization of' (Mathieu & Natalya, 2012).
- ODP initiative maintains a repository of a semantic wiki for their content description, discussion, evaluation, certification, etc.

[7] http://www.owlized.com/
[8] http://oegov.org/
[9] https://wordpress.com/
[10] https://www.whitehouse.gov/omb/e-gov/FEA
[11] http://ontologydesignpatterns.org/wiki/Main_Page

- In this library, ontologies are navigated by their domain, name, pattern type, event etc.
- ODP mainly uses Ontology Processing Language (OLP) syntax to match classes in ontology, which is written in OWL language (Aranguren et al., 2008).
- ODP express the n-ary relationship[12] to overcome the limitation of the representation language (Aranguren et al., 2008).

*ONKI***:** it is a Finland National Library joint project of the Ministry of Finance and the Ministry of Education and Culture**.** It is a centralized ontology directory which provides API services (Viljanenet al., 2010). It supports multiple languages, for instance, Swedish and Finnish. It is a kind of ontology service interface to build authentic, a centralized channel for the publication and utilization of ontologies and has a REST interface to integrate other applications (d'Aquin and Noy, 2012).

Features of ONKI (Viljanen et al., 2008)

- ONKI ontology server allows users to access and also download general ontologies on various areas such as Business, Culture, Health, Nature, and Public Administration etc. (Mathieu & Natalya, 2012).
- In this library, only administrators have the privileges to submit the ontologies.
- In ONKI server, ontologies are validated automatically.
- It provides unique identification and meaningful concept to make explicit relationships in the metadata descriptions.
- Ontologies are ordered by subject, publishing status, publisher, status and the kind of ontologies available.
- ONKI provides access to the ontology developers for the collaboration of ontology development and multiple versioning environments, for instance, ONKISKOS for lightweight vocabulary in SKOS, ONKIGeo for geo-ontologies with map support and ONKIPeople for representing people and organizations (Buitelaar & Eigner, 2008).
- ONKI provides the browsing facility.
- ONKI server has been integrated with content management systems (CMS) and mashup technology for indexing application.

DAML Ontology Library: the library has been designed under the DARPA agent markup language program to organize content, promote reuse and demonstrate adoption. Ontologies are submitted through web-based technology and enter into a MySQL database. The ontologies in the library are classified according to the DOMZ category, such as health, game, business, arts, society, sports, etc. (Ding & Fensel, 2001).

Features of DAML Ontology Library

- DAML provides the browsing facility.
- Normally, it contains catalogs for the ontology holding.
- This library system provides various file format (XML, HTML, and DAML etc.) for searching and browsing ontologies in the library.
- In this system, ontology stored in a specific format with different categories such as ontology URI, ontology id, description, keyword, POC (point to contract) name, organization, email, classes, namespace.
- It also has a specific form for submitting ontologies to the public DAML ontology library.
- The DAML ontology library provides unique URIs and IDs for identifying the existing ontologies.

4.3 Ontology Registry

MMI-ORR (Marine Metadata Interoperability- Ontology Registry and Repository): it is a web-based application developed by the Marine Metadata Interoperability Project**.** It is a kind of web-based architecture that allows users to create, access, modify and map their ontologies and vocabulary. MMI represents the ontologies in various forms (e.g. N3, TURTLE, RDF/XML, N-TRIPLE) in the context of the semantic web. It uses free text or a sophisticated search by using SPARQL query language (Mortensen et al., 2012).

Features of MMI-ORR (Rueda et al., 2009)

[12] http://patterns.dataincubator.org/book/nary-relation.html

- It assists users to view and access the ontologies.
- MMI-ORR collects ontologies from the registered users.
- MMI gateway provides tools that enable users to create and publish vocabulary in the standard RDF/XML, N3 format and also allows in mapping the ontologies.
- It uses OMV vocabulary for describing the ontologies.
- Its navigation criteria offers browsing facilities to users along with the URI, author, version, and the name of ontologies.
- Mapping editor VINE[13] enables data providers to create a mapping of ontologies between the service providers' terms and the portal categories by using a tabular based interface, Voc2RDF[14] tool which allows users to create controlled vocabularies.
- ONKI provides reasoned components to make automatic inferences and URI resolution, which enables better data discovery, integration, and processing capabilities.
- MMI-ORR uses NOAA/IOOS[15] variable which enables data provider to create ontologies and represents a portal category.

Protégé Ontology Library: Protégé ontology library is a kind of general ontology library which carries a different kind of ontologies in different formats. In this, ontologies are arranged in an alphabetical order. The library contains OWL and Frame-based ontologies including the others (e.g. DAML+OIL, RDFS etc)[16].

Features of Protégé Ontology Library[17]

- The Protégé Ontology Library provides ontology search and browse facilities.
- It enables users to download ontologies from the protégé ontology library page as well as from the dedicated homepage where the ontologies are available.
- The Protégé plugin library offers several open source and commercial Protégé plugins (e.g. Protege-nrepl, VOWL, NoHR, Snorocket, BNGen etc.) to improve the protégé application.
- Semantic MediaWiki extension generally used by the protégé wiki as a plugin in this library.

5. Evaluation of Ontology Libraries

5.1 Selection of Ontology Libraries for Evaluation

From the above list of various types of ontology libraries, we have identified ten libraries for the evaluation. This study exposes the selected libraries in terms of their technical, structural and infrastructural perspectives and their potential uses. One of the main objectives of this study is to recognize the existing significant ontology libraries along with their special features which will assist users, practitioners, and developers to further reuse for the application and also to publish their own ontologies into them. The libraries are selected for the evaluation based on the following constraints.

- Libraries have dedicated website and are available to access;
- Libraries have support to most of the popular file formats and allow import and export of ontologies;
- Use metadata;
- Support ontology mapping;
- Facilitate search within and across the ontologies;
- Allow users to upload and download ontologies.

5.2 Evaluation Criteria

After a thorough study of the literature, we have identified the following high-level characteristic of the ontology libraries. These characteristics are further applied back as evaluation criteria to evaluate the selected ontology libraries in the current study (d'Aquin and Noy, 2012).

*Specialization or field***:** In general, a library is not only designed based on any particular domain but may also cover multiple subjects, topics, information and artifacts in a single platform or place, whether in physical form or electronic form. Similarly, ontology libraries store a number of existing ontologies in a single place in several

[13] https://marinemetadata.org/guides/vocabs/cvchooseimplement/cvmap/cvmapvine
[14] https://marinemetadata.org/voc2rdf
[15] http://www.ioos.noaa.gov/
[16] http://protegewiki.stanford.edu/wiki/Protege_Ontology_Library
[17] http://protegewiki.stanford.edu/wiki/Protege_Plugin_Library

forms. Some of the libraries deal with a particular domain, while some of the libraries deal with multiple domains. For instance, BioPortal focuses on biomedical ontologies, while ONKI contains the ontologies in the field of Business, Culture, and History.

Browsing and searching ontologies: Seeking information is a most auspicious approach to enhance existing search within a collection of libraries and enable users to explore something new from them. But most of the libraries have unbounded access for the users to consume the existing ontology without registering with the libraries. Browsing is a major paradigm for exploring ontology libraries. Some of the libraries provide the faceted search and browse facility, for instance, by subject, structure, by language (e.g. German, Dutch and French). An ontology library may have initiated to assist users in searching an ontology of their interest, to provide flexible access to their applications, to provide a social platform for ontology developers and also to provide reasons for testing. The search facilities enable users to find outset of appropriate ontologies for further inference.

Submission process of ontology: The process of ontology submission totally depends on the particular ontology library. In general, the librarian is considered to be a gatekeeper of a library who collects all the information about book, articles and disseminate the information to the users. Gatekeeping rules are significant as on what basis ontology should be included in the library. This means the gatekeeper will evaluate the criteria of the ontology so that it can be decided whether that ontology needs to be within the repository or rejected. In the case of an ontology library, dissemination and validation of ontologies are usually done by a committee, an administrator and/ or the registered users based on the initial assessment. In some of the libraries, unregistered users can also submit their ontologies and the ontologies are validated through automatic syntax validation.

Mapping and relations: Ontology mapping means explicitly making the relationship between different ontology terms (e.g. classes, subclass, and individuals etc.,) by using logical axioms, logical equivalence, and reasoning rules. There are some libraries who provide the mapping facility. The Alignment server explores the storage, manipulation and export facility of a set of mappings. Khan et al. (2013) stated that basic ontology mediation must be supported in mapping the foundational ontologies to assist interoperability and interchangeability.

Web service access (APIs): Web service protocol provides set of flavors on metadata search, content search and query access like SPARQL. Most of the libraries do provide access to a web API service through Representational State Transfer (REST) and Simple Object Access Protocol (SOAP) based communication architecture for their ontologies. Different libraries may use different architectures to underpin their operation, for instance, of the selected libraries, few libraries use single server architecture to deliver their operations. Some of the ontology libraries are based on REST-based communication architecture to transfer their elements and operations.

Usage and access to ontology: The main purpose of designing a library is to provide access and promote proper use of the collection of library materials. Similarly, an ontology library is designed to provide access, view and download the existing ontologies to the users, and also to provide users the liberty to upload or publish modified ontologies in the library.

File format for input and output: Every ontology library has a standard file format for the ontologies whether we import or, export the ontologies. Standard ontology representation languages like OWL, RDF(S) and formal biomedical representation language like OBO are supported by most of the ontology libraries. Some of the ontology libraries also support OWL subset, namely, OWL Full, OWL DL, and OWL Lite.

Technology and interface: From the viewpoint of ontofier and ontologist, we always expect supremacy, scalability and robustness technology and user-friendly interface from ontology library. Few ontology libraries use standard technological components such as CVS as a software engineering tool, Protégé as an ontology editor, Watson as a semantic web search engine, SPARQL as a query language, Voc2RDF or VINE tool as a creation of controlled vocabulary and mapping editor, etc. With the help of these elemental components, a library makes the task of users simple and friendly.

5.3 Evaluation Result

The evaluation of the selected ontology repositories, directories and registries are accomplished based on the above-discussed evaluation criteria. Table 2 shows the result of our study. The table shows that among the repositories, BioPortal and AgroPortal are domain specific, while COLORE and ROMULUS are general and mixed base, respectively. We can also see from the table that all the repositories support the REST service protocol and also provide mapping services. It is worth to note that COLORE does not provide search service. The ontologies in COLORE are organized in a hierarchical order. Among the directories, OeGov is a domain specific (i.e., e-Governance), ODP is a generic directory, while ONKI and DAML deal with mixed ontologies. OeGov and ODP do not provide search service. It can be seen from the table that except ODP, none of the other directories have the mapping services. Among the registries, MMI-ORR is a domain specific, while Protégé library is a mixed based. Both of them provide the search and browsing facility and follow REST protocol.

Table 2: Result of the evaluation

		Features / Name	Specialization or Field	Browsing and Searching Ontologies	Submission process of ontology	Mapping and Relations	Web Service Access (APIs)	Usage and Access of Ontology	File Format for Input and Output	Technology and Interface
ONTOLOGY LIBRARIES	REPOSITORies	BioPortal	Biomedical	Browsing Hierar-chical order and Advance searching	Registered users	Mapping between classes	REST	Community Evaluation & Upload, Edit and Download	OWL, RDF, OBO, RRF	Protégé, LexGrid
		AgroPortal	Agronomic	Browsing and Advance searching	Registered users	Mappings between ontologies	REST	Upload, download	OBO, RDF, OWL, UMLS	Protégé, Web-Protégé
		COLORE	General	No support	Administrators and Registered users	Mappings between modules	REST	View and Download	XML, CLIF	Samian Platform
		ROMULUS	Mixed	Browsing Hierar-chical order and Searching	Administrators	Mappings between ontologies	REST	View and Download	OWL DL, OWL 2DL, OBO	WebProtégé
	DIRECTORies	OeGOV	e-Government	No support	Administrators via blog post	No support	No support	List of Ontologies description & View	OWL, RDF, N3	Wordpress
		ODP	General	No support	Registered users	N-ary Relation	No support	Design ontology for pattern reuse & View	OWL	MediaWiki
		ONKI	Mixed	Faceted browsing and Keyword based search	Administrators	No support	REST	Access general ontology, Upload, Download & View	RDF	Ad-hoc
		DAML Ontology Library	Mixed	Browsing by servlet interface and Searching but ontology listed by keyword	Organization and any users	No support	JENA	Access and View	RDF, DAML + OIL, OWL	Protégé
	REGISTRies	MMI-ORR	Marine Science	Browsing and Searching	Registered users or organization	Mapping across vocabularies	REST	View, Upload, Print and Download	OWL, RDF/XML, N3, JSON, CSV	Voc2RDF
		Protégé Ontology Library	Mixed	Browsing and Searching by Swoogle semantic web search engine	Registered users	Mapping between ontologies	REST	View and Download	OWL, DAML+OIL, RDFS	Protégé

7. Conclusion

The above study is conducted, as stated earlier, more than to comparing the ontology libraries, it is to understand the current practices of the ontology library developers. The study is conducted to explore the technological, structural and infrastructural aspects of the existing libraries. We envision that the present study will help the future developers and practitioners of ontology libraries in terms of implementing the essential features of an ontology library. The main limitation of the current study is, the study is based on the high-level features of an ontology library. In the future, we plan to do a much rigorous study. Some of the essential features (can be termed as low-level features) that we aim to look into are multiple metadata support, user interface, multilingual support, advanced search features, pictographic document, tool support for extracting and visualizing the graphs from the ontologies including the others.

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Biographies and acknowledgements

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