INTEROPERABLE MODEL FOR BIORESOURCE DISTRIBUTED DATABASES

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ABSTRACT:

Recently, numerous frameworks and tools are being developed for enhancing access to data and services with a standardized view to communicate the advances in open information sharing. Another emerging field of data exploration is encountered in the coordination, examination and perception of bioresource data and are prompting corresponding new innovations. The bioresource information team aims to develop standards for nationwide data exchange by the establishment of a catalog service to locate and access biological data and information from across the country and information tool for decision makers. With the growth of open data sharing initiatives, the sharing of data among different and myriad sources has increased significantly, but major challenge lies in addressing the issues of interoperability during exchange and use since the data sources are heterogeneous and the data being organization specific is prepared with different (organization) specific data standards and platforms. This paper presents the model based on the study of different metadata standards and to develop a recommended standard for biodiversity information to support interoperability among heterogeneous databases under the umbrella of Indian Bioresource Information Network (IBIN) portal. The paper presents the mapping of different data standards into the IBIN standard for sharing species data in the form of distributed and interoperable web services to set the stage for interoperability

Introduction

With the growth of open data sharing initiatives, the sharing of data among different systems has increased significantly, but major challenge lies during exchange and access since the data sources are heterogeneous and the data being vendor specific is dependent on the ways in which the data has been collected, labelled and stored in a specific standard and platform. However, data may be shared between two parties of same domain about with a simple longhand note, there is unquestionably a need for more documentation in the case of multidisciplinary teams working over multiple sites and scales.

The task of making data available across the domain and after some time is in general an unfunded mandate which requires a special kind of alertness to prepare a specific set of protocols for data in such a ways beyond what the user needs for its immediate utilization. The resultant specific set of protocols – data standards – are being developed to allow and ease the interconnection of disparate systems and thereupon the free flow of data. Data standards are characterized as a consensual specifications for the representation of data from heterogeneous sources or platforms. Data standards may be called as a benchmark required for the sharing, portability, and reusability of data (Chalmers 2006; Dudeck 1998; Kohn et al. 2000). Therefore, In order to understand the capacity of distributed and collective scientific work, there is a need to understand the standards, particularly, the forms and functions of 'metadata' – data about data – standards (Michener et al. 1997).

Metadata Standards

In various domains such as multimedia (Smith and Schirling 2006), educational resources (McClelland 2003), web (Bodoff et al. 2005), clinical research (Richesson and Krischer 2007), statistical methods (Bargmeyer and Gillman 2000), geospatial applications (Federal Geographic Data Committee 1998) and biodiversity (Costello and Wieczorek 2013) where the data is exponentially increasing on the order of petabytes annually, metadata was discovered in this digital era to help computer systems and human being in order to collect, organize, access and interpret data (van senbruggen et al. 2004; Kosch et al. 2005). Generally, metadata is loosely defined as "data about data".

According to the author of (Barkman et al. 2002), metadata is defined as

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"information about an object, be it physical or digital".

Thus, domain-specific metadata standards are the focal point in the rapid development of digital libraries and repositories (Chan and Zeng 2006; Fox et al. 1995). Basically, the users of such a digital world ""should be able to discover through one search what digital objects are freely available from a variety of collections, rather than having to search each collection individually" (Tennant 2001). Moreover, the aim of metadata is "to facilitate search, evaluation, acquisition, and use" of resources (Barkman et al. 2002). Various metadata standards have been developed, and many more are in the progress to meet the specific domain of interest, for example, DublinCore (DCMI 2007), USMARC (Carini and Shepherd 2004), Federal Geographic Data Committee (FGDC) (Federal Geographic Data Committee 1998), Survey Design and Statistical, Methodology (SDSM) (LaPlant et al. 1996), Ecological Metadata Language (EML) (Fegraus et al. 2005), Darwin core (DwC) (Wieczorek et al. 2012), and Metadata Object and Description Schema (MODS) and Metadata Encoding and Transmission Standard (METS) (Guenther and McCallum 2003).

As mentioned by the author of (Chan and Zeng 2006), metadata element set has two basic components:

- Semantics – This deal with the definitions of the meanings of the elements and their refinements.

- Content – This deal with the declarations or instructions of what and how values should be assigned to the elements.

The metadata element set and an appropriate vocabulary as values for the elements is a first step in describing any resource. Each element is repeatable and optional, and the entire set is extensible (Harper 2010)

Normally, metadata standards are categorized with respect to its application purpose, as business standard and technical standards (Vetterli et al. 2000). The technical metadata standards include schema definitions and configuration specifications, physical storage information, access rights, executable specifications like data transformation and plausibility rules, and runtime information like log files and performance results (Vetterli et al. 2000). However, technical standards are much more relevant because they played a key role in developing interoperable tools and services (Paepcke et al. 1998) and are required to support interoperability to distribute, create and manage data across platform.

Interoperability

The definition of Interoperability as given by Open Geospatial Consortium (OGC) is "the capability of a system or its components to repress the access obstacles to distributed resources forced by heterogeneous data and complex processing environments by means of a uniform interface" (Schell et al. 2000). In simple terms, Interoperability is considered as the capability to exchange and utilise information, typically characterized in the connection of a vast system made up of heterogeneous frameworks. OGC is now working not to develop another standard for geodata, but for the standard way for utilizing the existing standards in various applications in heterogeneous data environments and distributed processing applications (Schell et al. 2000).

Layers of Interoperability

There are various layers of interoperability identified in the literature, namely Protocol, Data Binding, Metadata Schemes, and Semantics, as listed in Table 1 (Duh et al. 2001). The topmost layer of interoperability is network protocol interoperability including TCP/IP and HTTP standards. These standards empower web browser and server to exchange messages in the form of request and response, despite of the different software components being developed and executed on different operating systems, hardware, etc. Second layer is data binding where data gets bound in particular format for representation, for example, representation of a document in HTML, XML and RDF is used for metadata binding. The third level that described in this paper is metadata scheme which provides the specifications of the data elements of which the metadata instance is composed of. Metadata instances based on a common metadata schema have a high degree of 'semantic interoperability' (Forte et al. 1999). The fourth and last layer is semantic that includes ontologies, classifications, vocabularies and taxonomies to define the domain specific concepts and their interrelationships.

Table 1. Layers of interoperability (*Source: Duval 2001*)

Protocol	TCP/IP, HTTP
Data binding	HTML, XML, RDF
Metadata scheme	LOM, Dublin Core
Semantic	Ontologies, classifications, vocabularies, taxonomies

Interoperability prevent end users from being averted into the proprietary systems by "enabling information that originates in one context to be used in another in ways that are as highly automated as possible" (Rust and Bide 2000). For example, World Wide Web (WWW) can be seen as a base of interoperable system that allow users to choose client and server (Berners-Lee, T. and M 1999). The challenges of metadata interoperability can be resolved at various levels, as mentioned by author of Haslhofer and Klas 2010:- "on a lower technical level, machines must be

able to communicate with each other in order to access and exchange metadata. On a higher technical level, one machine must be able to process the metadata information objects received from another. And on a very high, semantic level one must ensure that machines and humans correctly interpret the intended meanings of metadata."

Metadata Standards in Biodiversity

Bioresource information is fundamental and a key to decision making for a wide extent of scientific, educational, and governmental organizations. The term "biodiversity" comprises the diversities of plants, animals and other living things of a particular region or area (Heidorn 2002). The representation of biodiversity data are done using the principles of taxonomy. Taxonomy implies hierarchical approach to describe the organisms into different groups on the basis of their adapted characteristics and reflecting postulated evolutionary relationships between these groups (Paterson and Kennedy 2004). Henceforth, different taxonomic classifications and unambiguous labelling of these groups leads to a problem of integration and exchange of diverse datasets (Kennedy et al. 2006). This form of heterogeneity in biodiversity domain doesn't occur due to the non-standardized data storage but also because of diverse datasets and evolution of new form of information. The storage and distribution of bioresource information requires the integration of information on a single platform for data analysis and interpretation (Hoffmann et al. 2014). Seamless integrating and exchange of information from distributed sources into a single system is not a simple procedure, and therefore requires the need

of open data standards. The standards provide a definite set of rules and protocols to share information, making the integration much more straightforward to share the data. The use of standards will enable/enhance the interoperability among the systems for seamless integration of information. For example, non-governmental organisations such as International Organisation for Standardisation (ISO) uses standards and facilitates all the reciprocal needs of commercial and non-commercial needs of the community. The biodiversity related organisations such as government sector, natural history museums, universities and other private institutions are working on to develop common standardized model as a rule, protocol or guideline for exchanging data among them and supports distributed querying and responses for that queries. The globally reviewed metadata standards in biodiversity domain are researched and discussed in this section.

Review of Global Species Data Standards

When considering the task of sharing data– the specific data standards address the question of what information can be shared and the protocols address the question of how the information is to be shared and accessed. Following are the metadata standards supported for sharing different types of species data:

   i. Darwin Core
  ii. Ecological Metadata Language (EML)
 iii. Plinian Core
 iv. Species Profile Model (SPM)
  v. Access to Biological Collections Data (ABCD)

Table 2. Metadata Standards

Standards	Organization	Purpose	AccessURL
Darwin Core (DwC)	Taxonomic Databases Working Group (TDWG)	The Darwin Core is a metadata specification for information about the geographic occurrence of species and the existence of specimens in collections (Wieczorek et al. 2012).	http://rs.tdwg.org/dwc/
Ecological Metadata Language (EML)	Ecological Society of America	EML is a metadata specification particularly developed for the ecology discipline (Fegraus et al. 2005).	https://knb.ecoinformatics.org/
Plinian Core	Taxonomic Databases Working Group (TDWG)	Plinian Core is a standard oriented to share species level information (Working group for the development of the Plinian Core standard 2017).	https://code.google.com/p/pliniancore/wiki/About
Species Profile Model (SPM)	Taxonomic Databases Working Group (TDWG) and Encyclopedia of Life (EOL)	SPM is intended to be a specification of data concepts and structure intended to support the retrieval and integration of data that documents species, e.g., facts about biology, ecology, evolution, behaviour, etc. (TDWG 2016).	http://maps2.eol.org/info/98 http://wiki.tdwg.org/twiki/bin/view/SPM/SpeciesProfileModel
Access to Biological	Taxonomic Databases	It is intended to support the exchange of data about specimens and observations (ABCD	http://www.tdwg.org/activi

Collections Data (ABCD)	Working Group (TDWG)	2016).		ties/abcd/

With the growth of open data sharing initiatives, the sharing of data among different systems has increased significantly, but major challenge lies in addressing the issues of Interoperability during exchange and use since the data sources are heterogeneous and the data being vendor specific is prepared with different vendor specific data standards and platforms.

As the number of elements in the above defined metadata standards increases, the errand of facilitating metadata in different standards turns out to be more troublesome and monotonous. In order to minimize the expense of time for the creation and support of metadata and to maximize its convey to the wider audience of users, it should be desirable to develop a unique standard for species data to store and provide automated views of metadata. Using the core elements of the above defined data standards, a standard for bioresource information is defined for the interoperability between providers and Indian Bioresource Information Network (IBIN) portal. This paper presents the model based on the study of different metadata standards and to develop a recommended standard for biodiversity information to support interoperability among heterogeneous databases. The paper presents the mapping of different data standards into the IBIN standard for sharing species data in the form of distributed and interoperable web services to achieve interoperability. The

paper highlights the long ranged question of finding the finest long-range solution for facilitating data sharing and interoperability through the *"Web Services"*. Web services provide an open, interoperable, and highly efficient framework for implementing systems. Biodiversity data access through new software tools, web services, and architectures will convey new opportunities and dimensions to novel methodologies in ecological analysis, predictive modeling, and combination and representation of biodiversity information (Canhos et al. 2004).

Mapping of data elements

The mapping of various elements of different global metadata standards to IBIN standard is to be done by mapping the database attributes (fields) of the global metadata standards to the elements of the IBIN database schema. For instance, an attribute *TaxonRecordID* in the table of IBIN's local database corresponds to the *Dataset_ID* attribute in the Plinian Core. After accomplishing this step, the element set of the global metadata standards and their semantics will be mapped into the semantics of IBIN element set [11] which can be deployed in different application profiles in the form of web services and XML schema [**12**]. After mapping the elements, the data coming from heterogeneous sources will be published. The mapping is enlisted in Table 2.

Table3. Mapping of Different Standards into IBIN Schema

Category	Term Name	Standards	IBIN Standard	Use
Base Elements	DataSet_ID	Plinian Core	TaxonRecordID	Unique identifier of the record within the IBIN database.
	GlobalUniqueIdentifier	Darwin Core	GlobalUniqueIdentifier	Global unique identifier for the specimen or observation record.
	Description	Plinian Core	Abstract	Summarize the most relevant or attractive characteristics of this taxon to the general public.
	Basis of record	Darwin Core	RecordBasis	An abbreviation indicating whether the record represents an observation (O), a collected living organism, (L), a specimen in a collection/museum (S), a collected germplasm/seed (G), a photo (P), or derived from literature, where original basis unknown (D).
Nomenclature and Classification	Scientific Name	EOL SPM	Scientific Name	Canonical name enforcing strict inclusion of only

				nomenclatural information
	vernacularName	EOL SPM, Darwin Core, EML, Plinian Core	Common/ Vernacular Names	A list of common and vernacular names, in alphabetic order, optionally followed by language and region where it is used.
	Synonyms	EOL SPM, Darwin Core, EML, Plinian Core	Synonyms	A list of alternate scientific names by which the taxon is known.
	Hierarchy	EOL SPM, Darwin Core, EML, Plinian Core	TaxonomicHeirarchy	Hierarchical categories of the taxon
Description	General/Morphology/Life Form	EML, Plinian Core, EOL SPM	General/Morphology/Life Form	Description of the general appearance of the taxon; e.g body plan, shape and color of external features, texture, orientation and typical postures.
	Diagnostic Description	EOL SPM	Diagnostic	A description of the features that distinguish this taxon from close relatives or other similar species.
	TaxonomicalDescription	Plinian Core	SubspeciesVarietiesRaces Strains	Information on infraranks, *subspecies, varieties, races and strains*
NaturalHistory	Cyclicity	EOL SPM	Cyclicity	Those states or conditions characterised by regular repetition in time.
	Reproduction	EOL SPM	Reproduction	Description of reproductive physiology and behaviour, including mating and life history variables. Includes cues, strategies, restraints, rates.
	Migration	EOL SPM	Migration	Description of the periodic movement of organisms from one locality to another
	Dispersal	EOL SPM	Dispersal	Description of the methods, circumstances, and timing of dispersal
	Associations	EOL SPM	Associations	Descriptions (in narrative form) of taxa that interact with the subject taxon.
		EOL SPM	Diseases	Description of diseases that the organism is subject to.
MolecularCharacterisation	ChromosoneNumber	IBIN	ChromosoneNumber	Information on the cytology, genetics and biochemical details of the taxon
	Ploidy	IBIN	Ploidy	

	TotalDNAContent	IBIN	TotalDNAContent	
	MolecularChemicalMarkers	IBIN	MolecularChemicalMarkers	
HabitatLocationDistribution	Habitats	EOL SPM	Habitat	General description of the sites where the species is found.
	Location	Darwin Core, Plinian Core, EOL SPM	Location	Coordinates of the location where the taxon was sighted or the specimen collected.
	Distribution	Darwin Core, Plinian Core, EOL SPM	Distribution	Enumeration of geographic entities where the taxon lives.
DemographyConservation	Population Biology	EOL SPM, Plinian Core, EML	PopulationBiology	Information about the number of individuals per area or time unit and abundance information.
	Conservation	EOL SPM	ConservationStatus	A description of the likelihood of the species becoming extinct in the present day or in the near future.
	Legislation	EOL SPM, Plinian Core	Legislation	Legal regulations or statutes relating to the taxon - International, National or Regional.
UsesManagement	Uses	Plinian Core	Uses	Known or potential benefits of the species for humans, at a direct economic level, as instruments of education, prospecting, eco-tourism, etc.
	FolkKnowledge	Plinian Core	FolkKnowledge	Resources of folk knowledge related to the taxon.
	Management	Plinian Core	Management	Describes techniques and goals used in management of species - breeding and cultivation, control etc.
DatasetDetails	DatasetName	IBIN	DatasetName	Name of a related dataset
	DatasetPurpose	IBIN	DatasetPurpose	Purpose of the related dataset
	DatasetDescription	IBIN	DatasetDescription	Description of a related dataset
	DatasetLink	IBIN	DatasetLink	Link to the related dataset
Patent Details	PatentName	IBIN	PatentName	Name of the patent
	PatentNumber	IBIN	PatentNumber	Number of the patent
	PatentOwner	IBIN	PatentOwner	Name of the person in whose name the patent is issued.
	ProductProcess	IBIN	ProductProcess	Details of the product process.

	PatentDate	IBIN	PatentDate	Date on which the patent is issued.
	PatentLink	IBIN	PatentLink	Link, if any, to the patent details.
Specimen Details	TypeSpecimen	Plinian Core	TypeSpecimen	Type description. It could be: Holotype, Isotype, Isolectotype, Kleptotype, Paratype, Sintype.
	TypeCollector	Plinian Core	TypeCollector	Information about the person who collected the type specimen.
	TypeDate	Plinian Core	TypeDate	Date on which the type specimen was collected.
	TypeLocation	Plinian Core	TypeLocation	Locality where the type specimen was collected.
	TypeDepository	Plinian Core	TypeDepository	Name and Adress of Institution where the type specimen is hosted.
	TypeRecord	Plinian Core	TypeRecord	Record number of the type specimen in depository.
	TypeSource	Plinian Core	TypeSource	Online link (if available) to record in specimen depository.
Information Listing	Text References/Publications	IBIN	Text References/Publications	Compilation of all text resources and publications associated with/referred to/ cited in entire page.
	Documents	IBIN	Documents	Links to all documents on IBP referred to/associated with/ used in this entire page.
	External Links	IBIN	External Links	Compilation of all URL's in entire page that create outlinks from IBIN species pages into individual BRIC data providers' web sites.
Observational Information	Method	ABCD	TypeMethod	Method (including technical means) used to make the collection or observation
	AssociatedTaxa	ABCD	AssociatedTaxa	Gives information about the other taxa observed at the gathering site
	Sex	ABCD	SpecimenSex	sex of a specimen or collected/observed individual(s)
	Observed Weight	Darwin Core	SpecimenWeight	The total biomass found in a collection/record event. Expressed as kg
	SamplingEffort	Darwin Core	SamplingEffort	The amount of effort expended during an Event

	Temperature	Darwin Core	Temperature	The temperature recorded with the collection/record event
WMSURL	WMSURL	ABCD	WMSURL	Indicates URI (e.g. web address) for the location of a boundary polygon or centroid spatial reference relating to a gathering site, according to the Web Map Services (WMS) specification of the Open GIS Consortium.

Results and Discussions

This paper presented an approach to develop a toolkit through which the data coming from heterogeneous sources will be dynamically included into IBIN schema, prepared from data schema of globally understood standards. For this to happen, the compatibility of different standards used in IBIN standards and current existing standards is must which will be achieved by providing interoperability between systems on different platforms implemented by different technologies. Web Services provide a standard means of communication among different software applications, running on a variety of platforms and/or frameworks. The data will be published and indexed through the IBIN toolkit, and then the data will become available through IBIN infrastructure and can be used by the end users.

There are many challenges in developing and implementing this toolkit because web services and metadata standards are all new emerged technology and are undergoing changes and developments. The security of Services, the encryption of messages, and the common taxonomies to describe Services are all in need of consideration.

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