# Mapping People-centered Properties for Linked Open Data

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**ABSTRACT**
This paper describes a mapping of linked data vocabularies in the area of person-related information. Aligning vocabulary terms may help curb the problem of property proliferation that occurs in linked data environments. It also facilitates the process of choosing semantics for vocabulary extensions and integration in the context of linked data applications. Although a work in progress, this investigation would provide support for semantic integration and for knowledge sharing and reuse in the area of personal information representation. It also offers an opportunity to reflect on a new generation of knowledge organization systems such as linked data vocabularies that have started to populate the web and are converging with new representation models and discovery tools in libraries and other cultural heritage institutions.

"Mapping is neither secondary nor representational, but doubly operative: digging, finding and exposing on the one hand, and relating, connecting and structuring on the other."

-- Corner (1999)

## 1. Introduction

Recent developments in library data representation are creating new opportunities for metadata sharing, aggregation, and reuse. New models and standards, from FRBR and RDA to SKOS, are aimed at making catalog data available as machine-readable data across the web. These goals are in line with those of the Linked Open Data (LOD) initiative that recently emerged as the latest advance in the development of the semantic web.

Linked data is defined as "a set of best practices for publishing and connecting structured data on the web" (Heath n.d.). Based on a fairly simple representation framework that includes Resource Description Framework (RDF) as its data model and HTTP Unique Resource Identifiers (URIs) to globally identify entities, linked data has begun to populate the web with a massive amount of structured data intended to make content more sharable and re-usable.

Within the library community, the Library Linked Data (LLD) initiative has invested significant effort in moving its legacy data to the linked data environment. One of the goals of the LLD is to chart new channels for metadata dissemination and to promote new forms of data integration. The effort will enable seamless access to distributed and heterogeneous resources. Through linked data technology, bibliographic descriptions can be linked to resources from remote collections and repositories and can be enhanced with contextual information (e.g., geographic, biographic, etc.) derived from external datasets. Interlinking decentralized metadata with structured web data beyond existing controlled environments has the potential to create a new context of discovery and interpretation, the implications of which are still largely unexplored.

In a recent interview, Bernhard Haslhofer (Blumauer 2010) suggested that linked data technology represents a natural extension of the library practice of building knowledge organization tools, including metadata, controlled vocabularies, and identifiers. According to Haslhofer, linked data can be seen as "a natural technical evolution step in information organization" (para 4). For their part, libraries and other cultural heritage institutions have the potential to make a significant contribution to the linked data context by sharing their extensive collections of high quality metadata and authority data, providing a "backbone of trust" (Hannemann & Kett, 2010, 2). Despite its promise, much of the work is still in its early stages and a number of challenges need to be addressed before libraries, museums, and archives are able to take full advantage of linked data consumption (Coyle, 2010; Byrne & Goddard, 2010).

Beyond libraries, in the broader context of the web, the massive amount of linked data openly available has yet to be fully utilized. Linked data-enabled systems and applications are still in their infancy, but are undergoing rapid development cycles in a broad range of communities, from new media organizations to government agencies.

One of the strengths of linked data technology rests on its flexible modeling requirements that have facilitated the rapid development of a large number of open datasets and the continuous growth of the linked data cloud (Cyganiak & Jentzsch, 2010). Linked data vocabularies are RDF-based and as such share a common framework with the same modeling constructs that were specifically engineered for open and distributed environments. RDF vocabularies are easily augmented. For example, classes and properties can be 'imported' from other RDF vocabularies and integrated to enhance semantic expressivity. Classes and properties can also be refined by adding specificity through additional sub-classes and sub-properties. Virtually any RDF vocabulary can be enriched with terms from other linked data sets as well as local extensions then tailored to different representation domains and contexts of use.

This modeling flexibility also carries with it certain pitfalls. Concerns over the soundness of the conceptual description of linked datasets have begun to emerge in the literature. For example, the proliferation of classes and properties with overlapping scope has been identified as computationally problematic. There is an ongoing debate over the need to address the modeling issue of co-reference, which refers to the proliferation of new URIs pointing to the same 'things' (Uschold 2010). Aligning vocabularies is seen as conducive to reducing semantic heterogeneity and increasing consistency within the linked data environment. According to Jain, Hitzler, Yeh et al. (2010), without an alignment that creates a coherent and unifying framework for schemas, the possibility of interlinking between the many LOD datasets available is diminished and the potential advantages that could be obtained in terms of interoperability are reduced.

Mapping between vocabularies can also be beneficial to facilitating the reuse of existing data and schemas. The linked data community strongly encourages data reuse whenever possible as a way of reducing the intellectual effort needed to define new terms and avoid redundancies. Vocabulary mapping can support the selection of terms and facilitate the customizing of vocabularies to intended domains or datasets. Examples of

LOD vocabulary mapping are still scarce. Indeed, most linked data vocabularies are currently under development and only a few have reached stability and large adoption.

This paper reports on an ongoing mapping activity focused on a specific area of domain: people. This work aims to identify the range of descriptive elements available to represent people-related information in the linked data environment and map those elements for vocabulary alignment. It is part of a broader project investigating the application of LOD technology to create machine-readable descriptions of personal information in the context of digital archives. In this paper, the terms 'ontology' and 'vocabulary' are used interchangeably in line with current W3C guidelines (2010) that do not recognize, at least in terms of real-world applications, a strict boundary between the two tools.

## 2. Modeling people for web content representation

The entity *Person* is central to most knowledge organization systems. However, modeling individuals has seldom been an area of investigation per se. Bibliographic modes of representing people-related information are typically focused on authorship roles. *Person* entities are identified by their individual, familial or group names in line with the record-centric perspective of document discovery characteristic of the traditional library catalog. Metadata schemas also have little representation capability when it comes to people-centric descriptions. Referring to Dublin Core (DC), Nevile and Lissonnet (2004) argue that this limitation reflects the DC's original focus on resource discovery at the document level.

More granular descriptions of people entities are expressed by vocabularies developed by the semantic web and linked data communities. These vocabularies are driven by a representational paradigm centered on the notion of data as linkable units of content in line with Tim Berners-Lee's (2006) goal of creating a "Web of data" as an extension of the principles of the web from documents to data.

One of the first attempts to semantically represent individuals and their interests is the *Personal Ontology,* developed in 2000 by Jeff Heflin. This vocabulary was intended to support content annotation of basic home pages and was formalized in SHOE, one of the first web ontology languages.

The most successful vocabulary to represent personal information for web content was developed by the *Friend of a Friend* (*FOAF) Project* (n.d.). FOAF is a lightweight ontology used to describe people and resources using online personal profile information and social relationships. Initiated as a grassroots effort within the semantic web community, FOAF has become the core ontology for linked data publishing, with millions of profiles disseminated on the web (Feigenbaum et al., 2007).

The basic FOAF vocabulary defines a small set of classes and properties primarily intended to describe an individual's online presence, with the larger goal to create online communities. It includes properties representing personal information typically found on homepages, such as the name and email address of individuals, projects, interests, or links to other homepages. The key class of FOAF vocabulary is *Person,* which is a sub-class of *Agent.* FOAF defines only one property, *foaf:knows,* to represent social relationships. However, FOAF, as any RDF vocabulary, benefits from the mechanism of extensibility and, indeed, was programmatically designed to be used in combination with other schemas or ontologies (Brickley & Miller, 2010). FOAF has already been tailored to different representational domains and contexts (Mika & Gangemi, 2004; Graves, 2007). A list of FOAF extensions is available at the FOAF Project website (http://wiki.foaf-project.org/w/FoafExtensions).

## 3. Selection of Vocabularies

For the mapping proposed in the context of this paper, FOAF was identified as the appropriate reference vocabulary. FOAF is specifically centered on the entity *Person* and it is considered the de facto schema for person-related RDF applications. It has reached a relatively high level of stability and is extensively used to support integration of data across applications.

Eight additional vocabularies from linked data, as well as bibliographic, and cultural heritage domains, were selected for inclusion in the mapping. A list that includes namespace URIs, terms as prefixes by each vocabulary, and vocabulary specifications is shown in Table 1. Inclusion in the list was based on suitability to the subject domain, level of stability and usage, and availability of documentation. All the vocabularies provide, with various degrees of coverage, semantic representations of people-related information. Most of the vocabularies are widely used and have proven to work well in combination with one another (Bizer et al., 2011). Another condition for inclusion in the mapping was RDF format, either RDF born or implementations of RDF Schema. As this mapping is a work in progress, additional vocabularies deemed suitable are likely to be included in the future as they become available in required format for linked data applications.

| Vocabulary Name | Namespace URI | Prefix | Specification |
| --- | --- | --- | --- |
| Friend of a Friend (FOAF) | `http://xmlns.com/foaf/0.1/` | foaf | FOAF Vocabulary Specification 0.98 http://xmlns.com/foaf/spec/ |
| BIO | `http://purl.org/vocab/bio/0.1/` | bio | Bio Vocabulary 0.1 http://vocab.org/bio/0.1/.html |
| Relationship | `http://purl.org/vocab/relationship` | rel | Relationship Vocabulary http://vocab.org/relationship/.html |
| Cognitive Characteristics | `http://smiy.sourceforge.net/cco/rdf/cognitivecharacteristics.owl` | cco | Cognitive Characteristics Ontology 0.2 http://smiy.sourceforge.net/cco/spec/cognitivecharacteristics.html |
| SIOC Core Ontology | `http://rdfs.org/sioc/ns#` | sioc | SIOC Core Ontology Specification http://rdfs.org/sioc/spec/#sec-external |
| Dublin Core Metadata Terms | `http://purl.org/dc/terms/` | dcterms | DCMI Metadata Terms http://dublincore.org/documents/dcmi-terms/#H3 |
| The Bibliographic Ontology (BIBO) | `http://purl.org/ontology/bibo/1.3` | bibo | Bibliographic Ontology Specification http://bibliontology.com/specification |
| FRBR | `http://purl.org/vocab/frbr/core#` | frbr | Expression of Core FRBR Concepts in RDF http://vocab.org/frbr/core.html |
| CIDOC CRM | `http://www.cidoc-crm.org/rdfs/cidoc-crm` | [crm] | http://www.cidoc-crm.org/rdfs/cidoc-crm |

*Table 1. List of vocabularies participating in the mapping.*

The *BIO Vocabulary* describes biographical information (Davis & Galbraith, 2002). BIO models an individual's life as a series of interconnected events such as birth, divorce or graduation. BIO is used in combination with FOAF and most BIO properties have as a domain the class *foaf:Person.*

*Relationship Vocabulary* (Davis & Vitiello, 2004/2010) represents relationships between people from familial (e.g., grandchild of) to social (acquaintance of). Designed to refine the semantics of the property *knows* in the FOAF vocabulary, it includes only one class, *rel:Relationship*, while almost all its properties are defined as sub-properties of *foaf:knows*.

*The Cognitive Characteristics Ontology (CCO)* (Brickley et al., 2010) is a rather new vocabulary currently under development. It is based on existing vocabularies focused on the concept of interest and it is modeled on the FOAF vocabulary. Its value TO this investigation derives from ITS unique range of properties that characterize aspects of individuals such as interest and expertise.

*Semantically-Interlinked Online Communities Project (SIOC)* (Berrueta et al., 2004/2010) focuses on the description of information produced by online communities including blogs, mailing lists and discussion boards. SIOC is used in parallel with FOAF as a number of SIOC property terms are defined as sub-properties of FOAF.

While these vocabularies are specifically centered on people descriptions, the following vocabularies have been included to provide suitable classes and properties (or entitles and relationships, as these modeling constructs are named in other representation contexts).

*Dublin Core Metadata Terms* (DC Terms) (Dublin Core Metadata Initiative, 2010) is commonly used in LOD applications and it is often preferred to the core Dublin Core Metadata Set vocabulary because of the higher degree of precision of its property definitions. DC Terms are often used in combination with FOAF terms and the two vocabularies are currently among the ten most used in linked data applications. Just recently, the Dublin Core and FOAF communities have signed an agreement to cooperate for establishing best practices for vocabulary maintenance (Brickley et al, 2011).

*The Bibliographic Ontology (BIBO)* (Giasson & D'Arcus, 2008/2011) is a newly developed vocabulary for representing bibliographic entities including documents, citations and bibliographic references on the Semantic Web. It is still evolving and designed for being mixed with other vocabularies such as FOAF and Dublin Core and for being extended for local customizations.

*Functional Requirements for Bibliographic Records (FRBR)* offers a conceptualization of the "bibliographic record" structured as an entity-relational model and it has been implemented as an RDF Schema (Davis & Newman, 2005). The second of the three groups of FRBR entities includes the entity *Person* which is pertinent to the scope of this mapping.

*CIDOC Conceptual Reference Model (CRM*) (2010) is a core ontology expressing upper-level concepts common across cultural heritage documentation. Developed within the museum community, CIDOC CRM has the broader goal to enable semantically-rich information exchange between museums, libraries and archives. CIDOC CRM has been recently implemented in RDF.

## 4. Mapping structure and organization

Ontology mapping is defined as the process of finding correspondences between concepts from different ontologies in order to enable information processing across these ontologies (Noy 2009). Manually or automatically performed, ontology mapping is an active area of research in the semantic web community. However, specific work on the alignment of RDF-based vocabularies in the context of LOD development is limited (Jain, Hitzler, Sheth et al., 2010). Aleman-Meza et al. (2007) investigated RDF vocabularies' reuse and extensions, suggesting the need for a unifying framework for class and property alignment.

The nature and intended function of LOD vocabularies present a new perspective on term mapping. As discussed earlier, data sharing and reuse is at the core of LOD principles. It is made possible by the open and unifying nature of the RDF model. The RDF mechanism for uniquely identifying entities in an open and decentralized environment allows for different descriptive vocabularies or schemas to be mixed or used at the same time. Also, linked data vocabularies have relatively simple semantics. They are intended to describe large amounts of data, so their properties can be used with a higher level of openness and fewer formal restrictions.

This has implications for the ways in which ontology alignments are performed. While ontology mapping is conducted through the analysis of formal definitions of concepts and relationships, and thesaurus mapping focuses on the structural aspects of the terminology, the mapping of linked data vocabularies is less likely to be based on formal constraints.

## 4.1 Methodology

The mapping criteria considered in this study were *exactMatch* for equivalence relationships—also expressed by the *owl:equivalentProperty*—*closeMatch* and *relatedMatch* for associative relationshipsand, *broadMatch* and *narrowMatch* for hierarchical relationships. It should be noted that these criteria were loosely applied depending on whether term constraints (e.g., range, domain, etc.) were documented. Whenever possible, correspondences were based on the intended meaning of the terms as defined by specification descriptions published by the vocabulary governance agencies.

An inventory of properties was created to provide the basis for the mapping. In general, only that portion relevant to the entities *Person* or *Agent* (classes explicitly or implicitly declared in all the vocabularies) was used as the primary source of property terms. Three main categories for describing human characteristics emerged, including personal, online presence, and social and cognitive.

Samples from the three categories are presented below. Bold fonts indicate equivalence between terms. Broader and narrower terms are marked with one and two asterisks respectively. Domain was left blank when not declared. As the tables show, most of the alignments, especially when presenting partial overlapping semantics, remain implicit.

The property *foaf:maker*, not included in any specific category at the time of writing, is correlated across five of the vocabularies (see Table 2). This property offers one of the few examples in which a formal declaration of equivalence, *"dct:creator owl:equivalentProperty foaf:maker"*, is explicitly asserted by the vocabulary maintenance agencies. It is one of the first steps toward creating best practices for vocabulary alignment pursued by the cooperative agreement between the Dublin Core and FOAF communities.

| FOAF | | DCTerms | | BIBO | | SIOC | | FRBR | | CIDOC | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Property | Domain | Property | Domain | Property | Domain | Property | Domain | Property | Domain | Property | Domain |
| ***foaf: maker*** | owl: Thing | ***dcterms: creator*** | | *bibo: producer* | | *sioc: creator_of* | User | *frbr: creator* | | *crm: has_created* | Creation |

*Table 2. Sample of mapping of property 'foaf:maker.'*

The category of personal information includes a range of properties representing demographic characteristics (e.g., name, gender, etc.) and life events (e.g., birth, death, etc.). The listing below shows sub-properties of *foaf:knows* from the BIO and Relationship vocabularies. Interestingly, *bio:child* is a narrower term of *rel:childOf* as it strictly refers to a biological child and does not include adopted children, step-children or other types of similar non-biological relationships. This is also the case with *bio:mother* and *bio:father* that are intended as biological genitrix and genitor, while *rel:parent* explicitely refers to an individual who gave birth to or also nurtured and raised a person.

| | |
|---|---|
| *foaf:knows* | *foaf:knows* |
| *rel:parentOf** | *bio:mother*** |
| *rel:parentOf** | *bio:father*** |
| *rel:childOf** | *bio:child*** |

Properties describing the online presence of individuals and groups represent a relevant segment of both FOAF and SIOC vocabularies and provide a rather high level of specificity (Table 3).

| FOAF | | SIOC | |
|---|---|---|---|
| **Property Name** | **Domain** | **Property Name** | **Domain** |
| ***foaf:account*** | Agent | ***sioc:account_of*** | User |
| ***foaf:mailbox*** | Person | ***sioc:email*** | User |
| ***foaf:mbox_sha1sum*** | Agent | ***sioc:email_sha1*** | User |
| *foaf:member* | Group | *sioc:has_member* | Usergroup |
| *foaf:img* | Person | *sioc:avatar* | User |

*Table 3. Sample of mapping of online presence properties.*

Finally, the category of social and cognitive properties is characterized by terms expressing a broad range of human traits, from social connections to expertise, skills, and interests. A key property of this group is *foaf:knows.* This property denotes a non-specified reciprocal interaction between individuals (Brickley & Miller, 2010). However, semantic refinements are possible when used in combination with more specialized properties from other vocabularies, as discussed earlier. For example, several properties from the Relationship Ontology have been modeled as sub-properties of *foaf:knows* indicating various degrees of social and professional relationships. Examples of sub-properties of *foaf:knows* are preceded by a dash in Table 4.

| FOAF | | Cognitive Characteristics | | Relationship | | CIDOC | |
|---|---|---|---|---|---|---|---|
| **Property Name** | **Domain** | **Property Name** | **Domain** | **Property Name** | **Domain** | **Property Name** | **Domain** |
| | | *cco:activity* | | | | | |
| | | *cco:expertise* | | | | | |
| | | *cco:habit* | foaf:Agent | | | | |
| ***foaf:topic_interest*** | Person | ***cco:interest*** | | | | | |
| | | *cco:belief* | | | | | |
| | | *cco:competence* | | | | | |
| | | *cco:skill* | | | | | |
| | | | | *rel:influenced_by* | foaf:Person | *crm:was_influenced_by* | Activity |
| *foaf:knows* | Person | | | *-rel:mentor_of* | foaf:Person | | |
| *foaf:knows* | Person | | | *-rel:close_friend_of* | foaf:Person | | |
| *foaf:knows* | Person | | | *-rel:has_met* | foaf:Person | | |
| *foaf:knows* | Person | | | *-rel:knows_in_passing* | foaf:Person | | |
| *foaf:knows* | Person | | | *-rel:colleague_of* | foaf:Person | | |
| *foaf:knows* | Person | | | *-rel:acquaintance_of* | foaf:Person | | |
| *foaf:knows* | Person | | | *-rel:apprentice_to* | foaf:Person | | |
| *foaf:knows* | Person | | | *-rel:collaborates_with* | foaf:Person | | |

*Table 4. Sample of mapping of social and cognitive properties.*

This investigation shows that a broad range of properties allowing for rich descriptions of people entities is now available through RDF-based vocabularies. Vocabulary alignments are needed to help cope with the increasing proliferation of classes and properties with overlapping semantics. The experience of performing the mapping discussed in this paper has revealed some of the challenges of dealing with terms that frequently lack explicit definitions and indicates the need for establishing trustworthy practices of vocabulary development and maintenance.

## 5. Conclusion

This paper explores vocabulary mapping as a method to curb the problem of property proliferation that occurs in distributed digital environments. Aligning vocabulary terms also facilitates the process of choosing semantics for vocabulary extensions and integration in the context of linked data applications. The proposed mapping, although a work in progress, is intended to facilitate semantic integration as well as knowledge sharing and reuse in the area of personal information representation. Overall, this investigation aims to contribute to a new stream of research focused on modeling issues related to the description of people entities. It constitutes an initial step toward a general understanding of people-centered representation in the context of linked data research. It also offers an opportunity to reflect on a new generation of knowledge organization systems, such as linked data vocabularies, that have started to populate the web and are converging with new representation models and discovery tools in libraries and other cultural heritage institutions.

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