Linked Data Selectors

Kai Michael Höver
Technische Universität Darmstadt
Department of Computer Science
Hochschulstr. 10, 64289 Darmstadt
Germany
hoever@acm.org

Max Mühlhäuser
Technische Universität Darmstadt
Department of Computer Science
Hochschulstr. 10, 64289 Darmstadt
Germany
max@informatik.tu-darmstadt.de

ABSTRACT

In the world of Linked Data, HTTP URIs are names. A URI is dereferenced to obtain a copy or description of the referred resource. If only a fragment of a resource should be referred, pointing to the whole resource is not sufficient. Therefore, it is necessary to be able to refer to fragments of resources, and to name them with URIs to interlink them in the Web of Data. This is especially helpful in the educational context where learning processes including discussion and social interaction demand for exact references and granular selections of media. This paper presents the specification of Linked Data Selectors, an OWL ontology for describing dereferenceable fragments of Web resources.

Categories and Subject Descriptors

H.4 [**Information Systems Applications**]: Miscellaneous; K.3 [**Computers and Education**]: General

General Terms

Design

Keywords

Ontology, E-learning, Linked Data, Anchors

1. INTRODUCTION

In the world of Linked Data, HTTP URIs are used as names for things for referencing them. Furthermore, the Linked Data principles [3, 4, 5] recommend to make URIs dereferenceable, so that information about the referenced things are provided. These provided information might be embodied in the form of Web documents or represented as RDF data depending on, e.g., content negotiation. If a Web document has been requested, an HTML document that describes the resource is usually send back to the client.

Using URIs as names enables both humans and machines to talk about things like real-world objects or abstract concepts in an unambiguous way. However, a provided description of a resource might be too general. To take an example, you may want to refer to a certain paragraph of an HTML document or a certain section of a figure that is embedded in Web document. In these cases, using the URIs of the documents is not sufficient enough as they do not unambiguously refer to the indented fragments of a Web document.

Especially in the learning context the possibility to refer to a resource or a selection of a resource is necessary. We will explain this in the following.

As learning is also a social process, because learning processes include discourse, which is necessary to validate acquired knowledge and to learn from other people, learners debate and exchange information in, e.g., discussion forums or blogs. To take an example, if a forum discussion covers a certain slide or part of it, the reference to the discussion needs to be verbally expressed like "I have a question about presentation file x, slide number y, second equation". Using a URI instead that represents this selection is much more appreciated. To take another example, a teacher may want to refer to a specific time interval in a lecture video, e.g., from a MIT OpenCourseWare[1], it is fairly ponderous to describe the reference with words. Instead the teacher should provide a single link that unambiguously describes the interval. A last example regards the reference of a text section or sections. Imagine a student has a question regarding a specific paragraph in a long manuscript. Again, a link that describes the reference would ease the discussion about the referred section.

Further, making annotations to learning resources is also an important act of learning. Agosti et al. [1] distinguish between annotations as metadata, content, and dialogue acts. Annotations as metadata add information about the annotated information. Annotations as content augment information with additional content. A student or educator may add notes to an educational resource for explanation or clarification. Annotations as dialogue acts consist of communicative acts like a request or a discourse. For all these cases it is important to exactly *name* the related resource an annotation refers to. Studies regarding the annotation of texts have shown that the majority of annotations is anchored [15]. As educational content is not only textual but multi-medial, e.g., figures and videos, naming fragments of various media types for annotation anchoring is important.

According to Michael Joyce, hypertext can be used in both a exploratory and constructive way [13]. The selection of fragments and linking those fragments is one of the basic concepts of hypertext, which introduced a paradigm change from a linear to a non-linear arrangement of information. This brings along a new kind of knowledge organization and learning in contrast to former working with isolated and non-linked, linear information. Palumbo and Bermudez [16]

[1] `http://ocw.mit.edu/`

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argue that learners should become "builders of knowledge, inherently challenged to create new insights from the information provided". Therefore, they underline the importance that "the user not only browses the information base but also has the ability to build additional nodes and links". Selecting nodes and making links enables learners to organize unstructured information and to make implicit knowledge structures explicit. However, learners can only create their learning hyperspace if they are able to make fine-granular selections of elements in a learning ecosystem.

In order to address the outlined problems, we present the Linked Data Selectors (LDS) ontology, an ontology that specifies a vocabulary to describe fragments of various types of Web resources, and their representations. With this ontology it is possible to *name* selections of resources, to dereference them, and to link them.

The paper is structured as follows. First, we motivate the goals of the LDS ontology and then describe the design goals of the LDS specification. Then, we review the related work regarding the formalization of selectors. After this, the LDS ontology is presented. The paper closes with a summary and an outlook on future work.

2. DESIGN GOALS

This section describes the requirements and design goals for describing selections of Web resources.

2.1 Linked Data principles

Linked Data Selectors should fulfill the Linked Data principles [3, 4, 5]. These are:

1. Use URIs as names for things
2. Use HTTP URIs so that people can look up those names.
3. When someone looks up a URI, provide useful information, using the standards (RDF, SPARQL)
4. Include links to other URIs. so that they can discover more things.

Selectors should also be described by URIs and be dereferenceable to provide useful information.

2.2 Support of different media types

Web resources can be presented in various formats like HTML documents, figures, or videos. The MIME types [8] extend this list. Web documents can also be a combination of these types. For example, an HTML document with an embedded figure, or a presentation recording that may consists of figures, text, and a video. Depending on the type, different kinds of selectors are necessary. For example, an XPath description can be used to refer to nodes of an XML or (X)HTML document. For figures, geometric descriptions can be used to describe a shape that selects a portion. To obtain a selection of a Web database a SQL or SPARQL statement might be used. To enable selectors of a broad range of various Web resources, it is necessary to support different kinds of selection statements.

With a focus on digital media we can distinguish between:

- *Continuos media*: This category includes time-based media like audio and video. Selectors of this type are usually time instants or time intervals.
- *Discrete media*: Images, graphics, and texts are representations of discrete media. Digital images are usually described by either vectors or a coordinate system. For the latter, geometric shapes like rectangle or circle are often used for making selections of image regions.

2.3 Extensible and lightweight

As there are many different kinds of Web resources, it is necessary to make the specification flexible as possible. In particular, we need to support different kinds of media and appropriate selectors. Thus, namespace-based modules are used to allow extensibility. A selector can even be understood in a broader way as a thing that selects a part or parts from a thing. A selector could for example even be the eyes of a person, although our focus is on digital Web resources. As there are many different kinds of selectors we need to make the description of selectors and their selectors as flexible and extensible as possible.

3. RELATED WORK

In this section, we review existing technologies and ontologies that provide localization and selector concepts of digital information.

The Annotation Ontology [6, 7] provides a vocabulary to describe several types of annotations. It also includes selector concepts like *AudioSelector*, *ImageSelector*, and *TextSelector*, however they are only incompletely defined.

With the ISO/IEC MPEG–7 standard[2], formally named "Multimedia Content Description Interface", multimedia resources on the Web can be described. Particular localizations of a video can be localized. This includes region locators and spatiotemporal locators. Hunter [11], the COMM ontology [2] and other MPEG–7 ontologies [17] provide locator descriptions. Due to their focus on audiovisual information, they do not provide localization descriptions for textual information or information systems.

The XML Path Language[3] (XPath) is a descriptive language for querying nodes or atomic values in XML documents. As many applications use XML, for example SVG (Scalable Vector Graphics), Office Open XML, and XML-RPC , it can be used for querying information of various kinds of data.

The Structured Query Language (SQL) is a domain-specific language for managing data stored in relational database management systems. Queries can be performed with the `SELECT` statement.

The SPARQL Protocol And RDF Query Language[4] is the pendant of SQL for managing RDF data. The "SELECT" statement in combination with the WHERE clause enables pulling specific data out of SPARQL endpoints.

4. LINKED DATA SELECTORS ONTOLOGY

This section presents the design of the Linked Data Selectors (LDS) ontology, which we implemented in the W3C Web Ontology Language[5] (OWL).

First, we present the core modules of LDS ontology. Then, we describe the integration with other related ontologies.

[2]`http://mpeg.chiariglione.org/standards/mpeg-7`
[3]`http://www.w3.org/TR/xpath20/`
[4]`http://www.w3.org/standards/techs/sparql#`
[5]`http://www.w3.org/TR/owl2-overview/`

4.1 LDS core modules

The LDS-core ontology consist of two main concepts, that is *Selector* and *SelectionRepresentation* (see Figure 1).

4.1.1 Selector

A selector identifies a fragment of a specific resource. In Manchester syntax[6] [10], a *Selector* is formally defined as :

```
SubClassOf:
        fragmentOf exactly 1 Thing,
        hasRepresentation min 0
            SelectionRepresentation,
        hasSubselector max 1 Selector
```

A selection is made on a specific resource which is identified by the *fragmentOf* relation. As a selector can perform a selection on only one resource, this property is functional. Further, there can be one or more representations of a selection (see subsubsection 4.1.2). The *hasSubselector* object-property facilitates *selector chaining*. With this, a chain of selectors can be applied. Such a chain can be for example a region of an image which is the representation of a key frame of a time instant of a video.

Depending on the media type one of the following disjoint subconcepts is used:

- *TemporalSelector*: A temporal selector is used to identify fragments of time-based media like audio and video. Its selector is either a time instant or a time interval.
- *SpatialSelector*: This kind of selector identifies geometric regions of a two-dimensional image. A geometric region is described by a geometric shape like a circle or a rectangle.
- *DeclarativeSelector*: A declarative selector is used to make selections with declarative languages. This includes for instance XPath, SQL, and SPARQL.

4.1.2 SelectionRepresentation

The selection process may result in some representations. For example, the selection of an image can result in another image that contains the selected region; the selection of a video's time interval can result in a cut version of the original video. Selection representations are used to provide users one or more presentations of the result process. Such a representation refers to at least one resource of a certain media type.

4.1.3 SelectorSet

A *Selector Set* has the purpose to group selectors in order to speak about more than one *Selector* or *Thing*. With this, it is possible, e.g., to refer to a group of certain Web sites or several fragments of Web resources. Usually, a set of selectors consists of 2 or more Selectors, but may be also refer to a Resource Set[7] that describes a group of IRIs of resources.

4.2 LDS extended modules

In the previous section, the core features of the LDS ontology are presented. In this section, we describe the integration with other related ontologies. In particular, we need vocabularies for describing spatial and temporal selections as well as media types for describing a selection source and its representations.

4.2.1 Spatial selections

For describing spatial selectors (regions) on 2D images, we have modeled a simple ontology that defines the concepts of 2D shapes. Figure 2 depicts its class hierarchy. Common shapes for selecting parts of an image are circles and rectangles. A rectangle for instance is defined as a parallelogram which angle value is 90 (`hasAngle value "90"^^int`). Further it has a height and a width, and a coordinate identifying the point at the side of the rectangle with the smaller x-axis and y-axis coordinate value in the coordinate system. A circle is defined by its radius. The location coordinate points to the center of a circle.

4.2.2 Time-based selections

For describing time instants and time intervals a time ontology for synchronous media was defined. It consists of two main classes:

- *TimeEntity*: This class is the union of a class for describing time instants (*TimeInstant*) and time intervals (*TimeInterval*).
- *TimeUnit*: This concept is used for time unit conversion. It defines a base unit (seconds) and scaling numbers for derived time units like millisecond or minute.

4.2.3 Media

For the description of media resources we integrate the W3C Media Resources vocabulary[8], which provides a core set of metadata properties. It allows us to set the location of media resources as well as other metadata like *height* and *width* as well as *frame rate* and *duration* in case of video or audio resources.

4.3 Use by example

In this section, we present two examples that demonstrate using the Linked Data Selectors ontology.

4.3.1 Referencing a video snippet

Figure 3 depicts an example of using the LDS ontology. It shows the selection of a time interval of a video file, e.g., a lecture recording. The selection starts at second 23 and ends after one minute. A representation of this selection is provided at the URI "http://cutvideo.mp4".

4.3.2 Linking lecture slides with a paragraph of a Web document

In this example, we want to express the relation between a selection of a lecture recording and a related fragment of a Website. To be more precisely, we link a number of slides of the CLLS to a section of a HTML document. The CLLS (Collaborative Linked Learning Space) [12] is a system that stores data of lecture recordings and the corresponding learning space. This includes for example slides, lecture videos, user annotations, and meta data like keywords. In this scenario, we want to link all slides with the keyword "303 URI" to a fragment of the Linked Data Book[9] [9]. Here, we need to make the following two selections:

[6] `http://www.w3.org/2007/OWL/wiki/ManchesterSyntax`
[7] `http://www.w3.org/TR/2009/REC-powder-grouping-20090901/`
[8] `http://www.w3.org/TR/mediaont-10/`
[9] `http://linkeddatabook.com/`

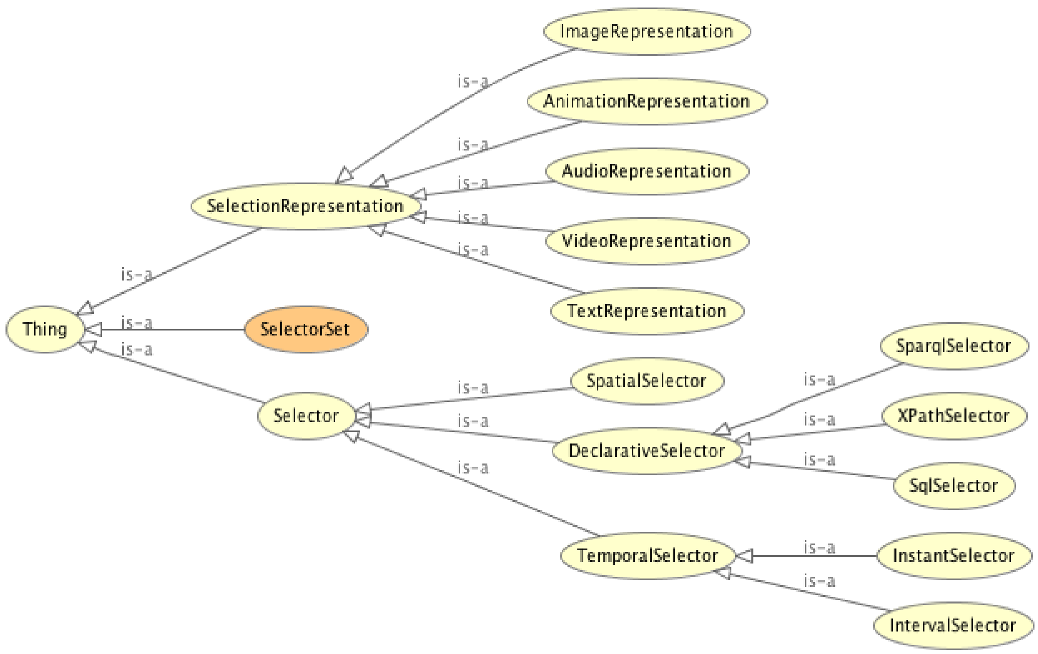

Figure 1: The Linked Data Selectors core ontology

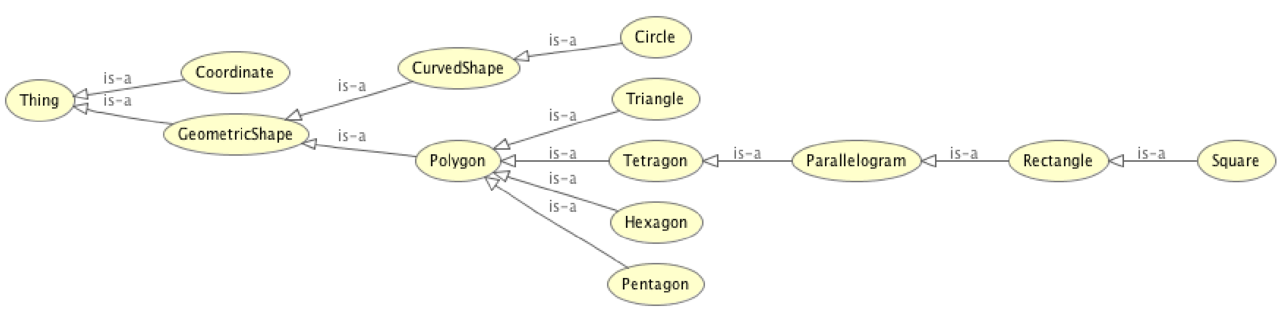

Figure 2: The class hierarchy of the Geometric Objects Ontology

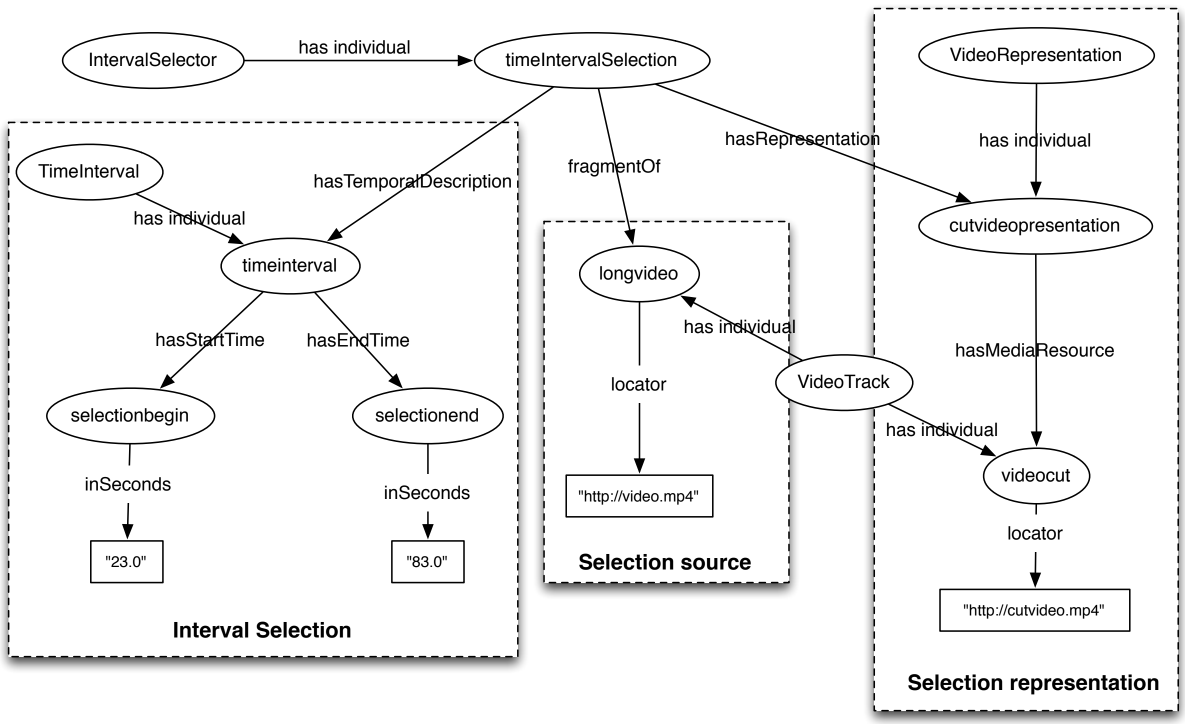

Figure 3: Example of the selection of a video segment and its representation

- Selection of slides: for the selection of slides we use a SPARQL query for the *SparqlSelector*:

  SELECT ?slide **WHERE** {
  ?slide a #Slide .
  ?slide dc:subject '303␣URI'.}

- Selection of paragraph: the paragraph of the book that provides an explanation of 303 URIs has the XPath */HTML/BODY/P[59]* that is used for the *XPathSelector*. This selection is a *fragment of* the document with the URL `http://linkeddatabook.com/editions/1.0/`.

The object property *#explains* from the CLLS namespace is used to describe the semantic relation between the slides and the paragraph. Figure 4 illustrates the example.

5. REVIEW OF DESIGN GOALS

- Linked data principles: By using RDF and OWL, e.g., instead of defining an XML schema definition, and reusing other ontologies, it is easily possible to publish and interlink selectors with structured data on the Web. URIs are used as names for selectors, which makes it much easier to talk about a selection. To take an example, it is possible to use an URI for the statements that refers to an SQL statement that selects all employees working in a certain department. Useful information (third Linked Data principle) can be provided by defining representations of a selection. Such representations can even include other URIs for further exploration.

- Support of different media types: The ontology is designed to support both continuous and discrete media types, as well as declarative languages like XPath and SQL. However, spatiotemporal descriptions are not supported. Though, it is possible to chain selectors.

- Extensible and lightweight: We achieve the extensibility via namespaces and via compliance with RDF. In this way, the specification can be extended without need of rewriting the core specification. Furthermore, there is no need of consensus of each element except the core elements, which is independent of other ontologies in its core version. Users can thus easily add module specifications that fits their needs.

6. SUMMARY AND FUTURE WORK

In a Web of Data it is not only important to make statements on resources but also about parts of these resources. This is especially relevant in the learning context since learning objects are available at different levels of granularity. For this purpose, this paper contributes the Linked Data Selectors ontology[10] that can be used for naming and (de-)referencing selections on media resources and their representation with HTTP URIs. We described the core of the ontology that is independent of any other ontology in order to meet the requirements of being extensible and lightweight(see section 2). Further, the integration of other ontologies was demonstrated, which was concluded by two examples.

For future work, we plan to refine and extend the ontology. For example, there is no support for selectors of spatiotemporal information. This could be integrated by making use of existing MPEG–7 ontologies. Furthermore, some resources like SQL or Web servers require user authentication. To extend the LDS ontology, vocabulary as defined

[10] `http://purl.org/lds/core/`

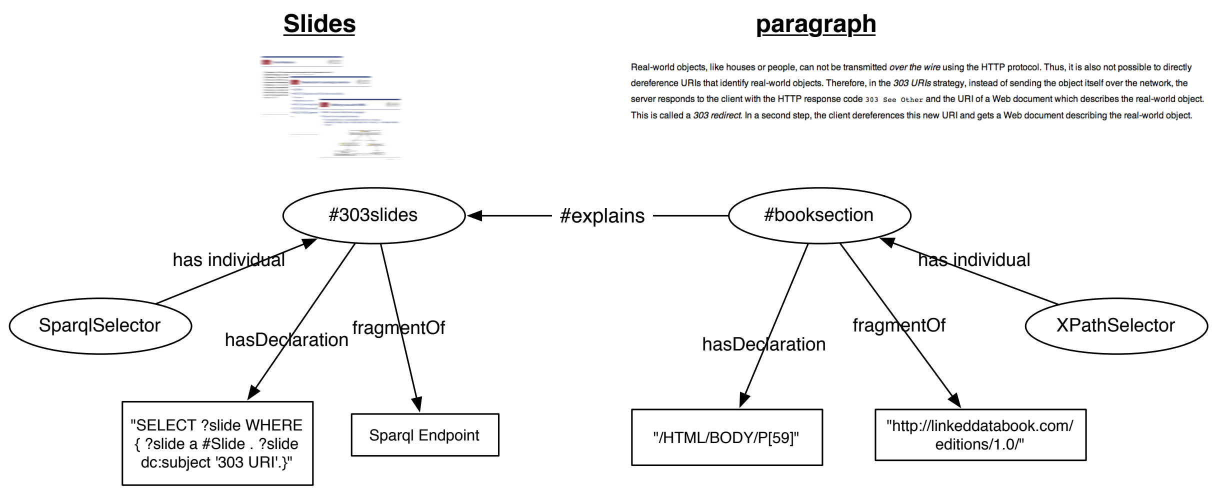

Figure 4: Example of linking a selection of slides and a Web document paragraph

by, e.g., the OmniVoke Authentication Ontology[11] [14] can be used for this purpose. Another interesting aspect is the dereferencing of Linked Selectors in combination with content negotiation and 303 URIs strategy for processing Linked Data Selectors.

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