

Yu, H.Q.; Pedrinaci, C.; Dietze, S.; Domingue, J.: Using linked data to annotate and search educational video resources for supporting distance learning. In: IEEE Transactions on Learning Technologies 5 (2012), Nr. 2, S. 130-142. DOI: <https://doi.org/10.1109/TLT.2012.1>

Using Linked Data to Annotate and Search Educational Video Resources for Supporting Distance Learning

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Abstract—Multimedia educational resources play an important role in education, particularly for distance learning environments. With the rapid growth of the multimedia web, large numbers of educational video resources are increasingly being created by several different organizations. It is crucial to explore, share, reuse, and link these educational resources for better e-learning experiences. Most of the video resources are currently annotated in an isolated way, which means that they lack semantic connections. Thus, providing the facilities for annotating these video resources is highly demanded. These facilities create the semantic connections among video resources and allow their metadata to be understood globally. Adopting Linked Data technology, this paper introduces a video annotation and browser platform with two online tools: Annomation and SugarTube. Annomation enables users to semantically annotate video resources using vocabularies defined in the Linked Data cloud. SugarTube allows users to browse semantically linked educational video resources with enhanced web information from different online resources. In the prototype development, the platform uses existing video resources for the history courses from the Open University (United Kingdom). The result of the initial development demonstrates the benefits of applying Linked Data technology in the aspects of reusability, scalability, and extensibility.

Index Terms—Distance learning, e-learning, educational video resources, Semantic Web, linked data, semantic annotation, semantic search, web services.

1 INTRODUCTION

IN the modern world e-learning activities are essential for distance learning in higher education. More than 5 million students have used or are using at least one online course in their studies, and the number of online students is growing by 25 percent every year [1]. The digital video, as one type of the multimedia educational resource, plays a key role in distance learning environments [2]. With rapidly growing numbers of digital educational video resources being created, it is important to accurately describe the video content and enable the searching of potential videos in order to enhance the quality and features of e-learning systems [3].

The Open University (OU) is the leading university in the United Kingdom for providing e-learning courses and it serves around 200,000 students at all degree levels. In collaboration with the British Broadcasting Corporation (BBC), the OU has produced a wide range of television programs (e.g., documentaries, historical event, news, and scientific programs) that can serve both students and general audiences.

Different OU departments manage their own educational resources separately because the resources, especially video

resources, are produced by different partners under heterogeneous licenses and constraints at different times. However, some resources are related to one another and can serve multiple courses. With the rapid growth of the multimedia web, a large number of free educational resources are also available on the web. Therefore, it is crucial to gain the capability to efficiently search for all related distributed educational resources together to allow them to be used to enhance the learning activities. To this end, this paper has identified the following primary challenges.

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- *Video resources should be described precisely.* It is difficult to use only one general description to accurately tell the whole story of a video because one section of the video stream may have plenty of information (e.g., on historical figures and hidden events in the conversations) but some of them might not related to the main points of the video when it was created. Therefore, the normal paragraph-based description process is not good enough for annotating videos precisely. A more accurate description mechanism, based on the timeline of the video stream, is required.
- *The descriptions of the educational resources should be accurate and machine-understandable, to support related-search functionality.* Although a unified and controlled terminology can provide accurate and machine-understandable vocabularies, it is impossible to build such a unified terminology to satisfy different description requirements for different domains in practice.
- *Linking video resources to useful knowledge data from the web.* More and more knowledge and scientific data is

published on the web by different research and educational organizations (e.g., Linked Open Data [4]), and so it is useful to break the teaching resource boundaries between closed institutions and the Internet environment to provide richer learning materials to both educators and learners.

This paper adopts Semantic Web technology, more precisely, the Linked Data approach to address the above challenges. The following lists the major contributions of our approach.

1. A video annotation ontology is designed by following Linked Data principles and reusing existing ontologies. It provides the foundation for annotating videos based on both time instance and duration in the video streams. This allows more precise description details to be added to the video.
2. A semantic video annotation tool (Annnotation) is implemented for annotating and publishing educational video resources based on the video annotation ontology. *Annnotation* allows annotators to use domain specific vocabularies from the Linked Open Data cloud to describe the video resources. These annotations link the video resources to other web resources.
3. A semantic-based video searching browser (SugarTube) is provided for searching videos. It generates links to further videos and educational resources from the Linked Open Data cloud and the web.

The remainder of the paper covers background and related work discussions (Section 2), the overall platform architecture (Section 3), the detailed illustration about the annotation process and the Annnotation tool (Section 4), the detailed description about the SugarTube browser (Section 5), lessons learned from the survey-based evaluation process (Section 6), and the conclusion and future work (Section 7).

2 BACKGROUND AND RELATED WORK

2.1 Requirements for Enhancing Educational Video Resources to Assist in Distance Learning

Videos are important educational resources that enable students to gain knowledge more efficiently and intuitively than text-based educational resources. Video resources play an important role in distance learning courses (e.g., history courses). For example, a five-minute long video of a speech may contain plenty of information such as event background, location, time and related people. However, traditional educational video resources usually lack labeled vocabularies and structured metadata. These drawbacks limit the usability, efficiency, and reusability of the educational video resources.

To improve e-learning outcomes, educational video resources should have accurate and collaborative annotations generated by domain experts, course creators, and tutors. It is important that the annotation vocabularies are accurate, identifiable, and sharable between different groups of people. Furthermore, if each piece of the annotation in the videos is detailed with further information, this would help students to view a more complete

picture of a learning topic. Moreover, if these annotations are linkable to other relevant learning data from both internal and external resources, then it would enable students to gain a more comprehensive understanding of the topic from different perspectives.

2.2 Semantic Web, Linked Data, and Web Services

The Semantic Web [5] is an evolving development of the World Wide Web, in which the meanings of information on the web is defined; therefore, it is possible for machines to process it. The basic idea of Semantic Web is to use ontological concepts and vocabularies to accurately describe contents in a machine readable way. These concepts and vocabularies can then be shared and retrieved on the web. In the Semantic Web, each fragment of the description is a triple, based on Description Logic [6]. Thus, the implicit connections and semantics within the description fragments can be reasoned using Description Logic theory and ontological definitions. Earlier research work on the Semantic Web focused on defining domain specific ontologies and reasoning technologies. Therefore, data are only meaningful in certain domains and are not connected to each other from the World Wide Web point of view, which certainly limits the contributions of Semantic Web for sharing and retrieving contents within a distributed environment.

Linked Data [7] is the recent revolutionary development of the Semantic Web. Linked Data create typed links between different data from different resources. From the technical point of view, Linked Data means to publish data on the web in such a way that they are readable by machines and their meanings are explicitly expressed. These data are then linked to external data sets, and in turn are linked from external data sets [8]. Linked Data changes the way of organising knowledge-based resources on the web by using the following four principles [8]:

1. Data are identified by URIs,
2. the URIs can be dereferenced,
3. the dereferenced data contain more useful information about the data, and
4. more data are easily discoverable on the web scale.

Linked Data can be easily queried through SQL-like languages (e.g., SPARQL [9]). The most promising data set of Linked Data is the Linked Open Data cloud [4] (see Fig. 1) that includes data in seven different areas such as media, geographic, publication, user-generated content, government, cross domain, and life science.

Linked Data are published through web services in order to be accessed by various applications. In particular, resource-oriented RESTful web services [10] are naturally matched to the characteristics of publishing the Linked Data resources [11] into SPARQL endpoints.

In this paper, the services for retrieving Linked Data are defined as Linked Data Services in order to distinguish them from other services that do not deal with Linked Data.

The following summarizes four most important advantages of using Linked Data to create video annotations for the educational domain.

- *Each video annotation is unique and explicitly identified.*
Each piece of Linked Data is identified by a URI that

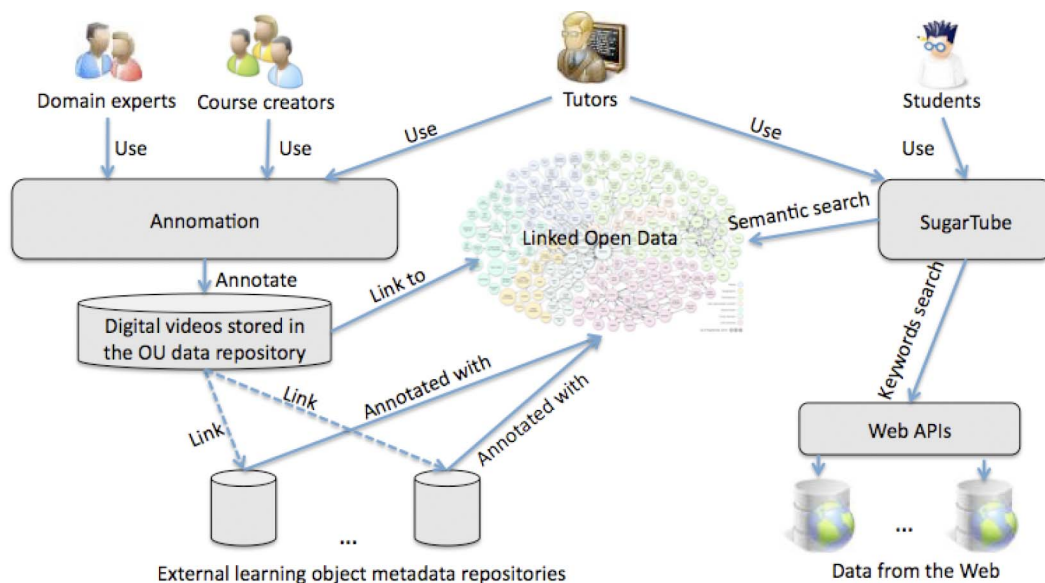


Fig. 2. The overall architecture of Annomation and SugarTube.

on adding semantic tags to the user's search inputs (e.g., [20]). However, most of these approaches require machine-learning mechanisms to assist dynamically adding tags. Hence, they restrict their applications to small and closed domains of discourse.

3 THE OVERALL ARCHITECTURE

Our approach adopts the principles of Linked Data to annotate the existing OU educational video resources and link them to other relevant resources on the web. Fig. 2 shows the overall architecture of the annotation and browser system, namely Annomation+SugarTube.

There are four groups of users:

- *domain experts* who are specialists in identifying items on the video for certain courses. In our prototype development, the experts are people working in the history department who are familiar with the OU video collections;
- *course creators* who are in charge of defining the syllabus and teaching plans for certain courses;
- *tutors* who execute the syllabus and teaching plans to create the detailed teaching materials and provide support for students within the distance learning environment;
- *students* are the learners who take the distance learning courses.

Annomation is a collaborative Linked Data-based annotation platform that allows domain experts, course creators, and tutors to annotate videos using vocabularies from the Linked Open Data Cloud for different types of information (e.g., GeoName vocabularies for locational annotations). As mentioned earlier, the usage of Linked Data makes annotations accurate, distinguishable, and deferencable. Furthermore, these annotations are published as Linked Data. Therefore, they are linked to other related external educational resources annotated by semantically related Linked Data vocabularies.

SugarTube provides an online browsing platform that allows tutors and students to browse and search videos that are annotated by Annomation. It offers both syntactic and semantic search functionalities. The semantic search API not only finds video from the OU video repository but also delivers any linked educational resources from the Linked Open Data cloud to the user interface. The syntactic search offers more syntax-based related educational resources from the web.

The details of Annomation and SugarTube are discussed in Sections 4 and 5, respectively.

4 ANNOTATION: COLLABORATIVE LINKED DATA-DRIVEN VIDEO ANNOTATION

Annomation² is a web application that allows users to view a video in a collaborative way, pause it, and add Linked Data annotations to instants or durations on the video timeline.

4.1 Video Annotation Ontology

The video annotation ontology and annotation instances are stored in a Sesame RDF [21] quad store, and the ontology reuses a number of RDF vocabularies. These vocabularies include:

- *Friend-of-a-Friend* [12], for identifying users and their accounts. Specifically, an OpenId URI is used as the identifier.
- *The Timeline ontology* [22], for identifying temporal instants and durations on the video timeline.
- *Dublin Core*, in its RDFS form,³ for metadata such as a video's title, and the author and creation time of each annotation.

To tie together the data described using these vocabularies, we designed a small vocabulary specific to the annotations, the core of which is:

2. <http://annomation.open.ac.uk/annomation>.

3. <http://www.dublincore.org/schemas/rdfs>.

```

/* The namespaces of used ontology are
   declared */
@prefix : <http://annomation/annomation/
ns/annomation #>.
@prefix owltime: <http://www.w3.org/TR/
owl-time/#> .
@prefix foaf:
<http://xmlns.com/foaf/spec/20100101.
rdf/#>.

```

```

/* We introduce extra classes to the
annotation on- tology */
:MediaResource a rdfs:Class.

```

```
:Video a rdfs:Class.
```

```
:Annotation a rdfs:Class.
```

```
:Mood a rdfs:Class.
```

```

/* We define extra necessary properties that
is used to describe the annotations */

```

```

/* "fronts" specifies that a video is a media
resources */

```

```

:fronts a rdfs:Property;
  rdfs:domain :Video ; rdfs:range
  :MediaResource .

```

```

/* "mood" and "topic" together specifies the
type of an annotation, it can be an annotation
that annotates a conversation in the video,
video stream itself or the audio stream in the
video on a point or duration of the video
timeline */

```

```

:mood a rdfs:Property ;
  rdfs:domain :Annotation ; rdfs:range
  :Mood.

```

```

:topic a :Mood ;
  rdfs:label "Topic of conversation"@en.
:inVideo a :Mood ;
  rdfs:label "In video stream"@en .
:inAudio a :Mood ;
  rdfs:label "In audio stream"@en .

```

```

/* "annotates" specifies the time point or
duration of an annotation */

```

```

:annotates a rdfs:Property ;
  rdfs:domain :Annotation ; rdfs:range
  owltime:TemporalEntity .

```

```

/* "reference" is the actual content of the
annotation */

```

```

:reference a rdfs:Property ;
  rdfs:domain :Annotation ;
  rdfs:range rdfs:Resource .

```

```

/* "creator" indicates who create the
annotation */
:creator a rdfs:Property ;
  rdfs:domain :Annotation ; rdfs:range
  foaf:Agent .

```

```

/* "onTimeline" specifies the time point or
duration of an annotation belonging to a
certain video */

```

```

tl:onTimeline a rdfs:Proerty;
  rdfs:domain owltime:TemporalEntity;
  rdfs:range :Video .

```

A simplified high-level ontology explanation is that each annotation is created by a user for an instant or time duration on a video. An annotation example that ignores the namespace is listed below:

```

/* RDF resource :/resource/2d917907a7d9 is a
Video (the video resource identifier is :
/video/cu31648) and titled "Woods/East
Berlin" */

```

```

<rdf:Description rdf:about=":/resource/
2d917907a7d9">
  <rdf:type rdf:resource=":#Video"/>
  <anno:fronts rdf:resource=":/video/
cu31648"/>
  <dc:title>Woods/East Berlin</dc:title>
</rdf:Description>

```

```

/* RDF resource :/resource/abae6b358da8 is a
interval unite on a duration between
PT00.000S and PT01M56.000S of RDF resource :/
resource/2d917907a7d9 */

```

```

<rdf:Description rdf:about=":/resource/
abae6b358da8">
  <rdf:type rdf:resource="timeline.owl#
Interval"/>
  <tl:onTimeline rdf:resource=
"/resource/2d917907a7d9"/>
  <tl:at rdf:datatype="XMLSchema#
duration">
  PT00.000S</tl:at>
  <tl:duration rdf:datatype="XMLSchema#
duration">
  PT01M56.000S</tl:duration>
</rdf:Description>

```

```

/* RDF resource :/resource/4b91890913d4 is
an annotation on RDF resource :/resource/
abae6b358da8 (see above) using http://
dewey.info/class/943 with default mood and
the annotation is created on date and time of
2010-09-16T15:01:26 */

```

```

<rdf:Description rdf:about=":/resource/
4b91890913d4">

```

```

<rdf:type rdf:resource=":#Annotation"/>
<anno:annotates rdf:resource=
  ":/resource/abae6b358da8"/>
<anno:reference rdf:resource=
  "http://dewey.info/class/943/">
<anno:mood rdf:resource=
  ":/ns/annomation#topic"/>
<dc:creator rdf:resource=
  ":/resource/519a723bf793"/>
<dc:date rdf:datatype=
  "XMLSchema#dateTime">
  2010-09-16T15:01:26Z</dc:date>
</rdf:Description>

```

4.2 Using Linked Data to Annotate Videos

Traditional video annotations using free-text keywords or predefined vocabularies are insufficient for a collaborative and multilingual environment. They do not properly handle the annotation issues, such as accuracy, disambiguation, completeness, and multilinguality. For example, free-text keywords annotation easily fails on accuracy issues as they may contain spelling errors or be ambiguous. Furthermore, they are insufficient for a collaborative and multilingual environment.

Our approach uses Linked Data to tackle the above issues in video annotations. It brings the following benefits.

- Each vocabulary is controlled and accurately defined in the Linked Data Cloud. It owns a unique URI to distinguish it from other vocabularies, so there are no conflicts between different vocabularies and meanings.
- Different vocabularies, which describe the same thing, are linked using the *owl:sameAs* property as an equation definition. Meanwhile, a number of semantic annotations are used to build the relationships between different vocabularies, such as *rdfs:subClassOf* and *rdfs:seeAlso*. Once a vocabulary is applied to an annotation, the related vocabularies are associated with the annotation. Therefore, the collaborative and multilingual issues are well addressed.
- The Linked Open Data Cloud, which has the most complete data sets to describe the current world, helps to find a good number of related educational resources.

Five Linked Data Services are currently used as a foundation to annotate videos, and they are embedded in the Annomation functions to facilitate the annotation process. More services can be easily added into the system by adding a tab option to show the query results of the new service when required. The five Linked Data Services are:

- *Dewey Decimal*: The top level Dewey Decimal Classification (covering the first three digits of a Dewey number) has been published in RDF form by the Online Computer Library Center,⁴ and the resulting taxonomy is presented to the annotator as a browsable tree.

- *Library of Congress classifications*: The Library of Congress has published its entire classification system in RDF,⁵ but this is much too large to present directly to the user. Instead, Annomation provides an interface to the Library of Congress keyword search service, which returns suitable RDF files for the user to choose from.
- *GeoNames* [23]: The GeoNames API is used to identify named locations using a keyword search, or to perform reverse lookup to find named locations in a vicinity. The results provide the position and the category information with URI identifiers.
- *OU Bluelist*: An OU service is used to get Open University course taxonomies.
- *Zemanta* [24]: A service which provides analysis of natural language text to identify various concepts and named entities returning their URIs to Linked Data such as DBpedia and Freebase.

4.3 Annomation Implementation

The Annomation interface (see Fig. 3) is divided into four sections: a Flash video player (top left); a list of current annotations (top right); controls for the video player, and for entering new annotations (across the centre) and a set of panels to help the user to find new Linked Data URLs (bottom). The bottom panels provide quick access to previously used tags, to the Dewey and Library of Congress classifications schemes, Open University course taxonomies, a service for suggesting URLs based on the Zemanta service, and a visual map tool that uses GeoNames to find named geographical entities.

The system is implemented in the Clojure language [25], using Sesame as an RDF quad store, and RDF2Go⁶ as an abstraction over the store. Annomation provides programmatic APIs in the form of a SPARQL end point for querying and RESTful interfaces for adding and removing annotations, and exploring existing ones. The client side uses Javascript with the Yahoo YUI library⁷ and the JQuery plugin RDF Query,⁸ and FlowPlayer⁹ for video playback. OpenId [26] is used for user identification and authentication.

5 SUGARTUBE: SEMANTICS USED TO GET ANNOTATED VIDEO RECORDING

SugarTube¹⁰ is developed to facilitate the usage of the OU's educational video resources that are annotated by Annomation. It adopts the Semantic Web approach to search videos and explore their related online resources in a mashup navigation interface. In SugarTube, the annotations are semantically matched to other annotated educational resources from the web.

The SugarTube application includes three layers. Users interact with the *application layer* when specifying the concepts, documents (e.g., lecture notes), or website contents in order to get educational video resources. Based on different types of concept data, user requests are then sent

5. <http://id.loc.gov/authorities>.

6. <http://semanticweb.org/wiki/RDF2Go>.

7. <http://developer.yahoo.com/yui>.

8. <http://jquery.com>.

9. <http://flowplayer.org>.

10. <http://sugartube.open.ac.uk>.

4. <http://dewey.info>.

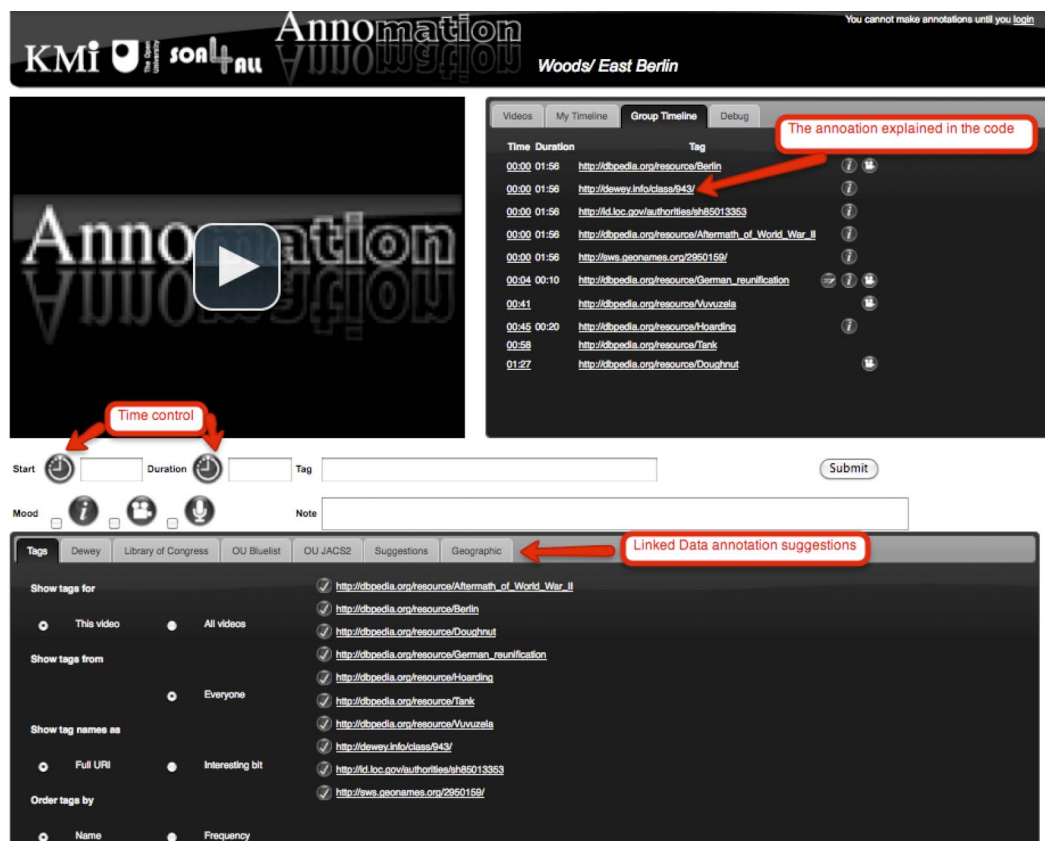


Fig. 3. A snapshot of the Annomation interface.

to the *semantic data mining and reasoning layer* for generating different queries to the *service layer*. The service layer includes both Linked Data Services and nonsemantic-based services.

5.1 Service Layer

In addition to the Linked Data Services that are applied in the Annomation process, some other Linked Data Services and nonsemantic services are used in SugarTube. The Linked Data Services are:

- *WorldHistory*¹¹ that provides API access to retrieve the information about people, events, places, and genealogy in history;
- *The OU Linked Data*¹² that is currently under development and aims to extract and interlink previously available educational resources in various disconnected institutional repositories of the Open University and publish them into the Linked Open Data cloud; and
- *Sindice* [27], [28] that is a semantic search engine, which crawls and collates the Semantic Web (including microformats), and provides services such as keyword-based searching for linked data and accessing cached fragments of the Semantic Web.

In order to reuse the data sets and services listed above, we use two ontologies: the Simple Knowledge Organization System (SKOS) [29] and the WGS84-based RDF vocabulary for geographical data [30].

11. <http://www.worldhistory.com/api>.
 12. <http://data.open.ac.uk>.

The nonsemantic services are:

- *BBC Web API*¹³ that offers machine readable program information;
- *Map Services* that provides interactive Ajax mapping services from Google¹⁴ and Yahoo;¹⁵
- *OpenLearn* [31] that gives free access to a subset of the Open University's course resources, along with metadata; and
- *YouTube data services*¹⁶ that finds videos via a keyword-based search.

5.2 Application Layer

The SugarTube functionalities are divided into two groups, namely *basic concept search* and *advanced search*.

The basic concept search divides the concepts into "Person," "Event," "Place," and "Others." For different types of concepts, different service queries are generated. For instance, searching by the name of a person queries the *searchByPerson* WorldHistory service, while searching by the name of a place queries the *searchByName* GeoName service.

The advanced search supports searching videos by automatically analyzing documents, highlighting web contents, and pointing to locations on a map. Behind this, the Zemanta¹⁷ service is used. For example, when a user copies and pastes the learning content from lecture notes into the

13. <http://backstage.bbc.co.uk/data/BbcWebApi>.
 14. <http://code.google.com/apis/maps>.
 15. <http://developer.yahoo.com/maps>.
 16. <http://code.google.com/apis/youtube>.
 17. <http://www.zemanta.com/service>.

```

<gn:alternateName xml:lang="tr">Cape Canaveral</gn:alternateName>
<gn:alternateName xml:lang="zh">卡纳维拉尔角</gn:alternateName>
<gn:featureClass rdf:resource="http://www.geonames.org/ontology#T">
<gn:featureCode rdf:resource="http://www.geonames.org/ontology#T.CAPE">
<gn:countryCode>US</gn:countryCode>
<wgs84_pos:lat>28.45861</wgs84_pos:lat>
<wgs84_pos:long>-80.5331</wgs84_pos:long>
<wgs84_pos:alt>1</wgs84_pos:alt>
<gn:parentCountry rdf:resource="http://sws.geonames.org/6252001/">
<gn:nearbyFeatures rdf:resource="http://sws.geonames.org/4149910/nearby.rdf"/>

```

Fig. 4. Syntax parsing results.

textfield, all related knowledge concepts are listed, which enables the user to select further video searching activities. The Google map service is deployed for gathering the geoinformation about a place so that the user may click on the map to search related videos. The searching results do not only contain the OU educational video resources with their annotations but also include relevant learning resources about the videos and related videos from other services.

5.3 Semantic Data Mining and Reasoning Layer

There are four different types of mining and reasoning processes: namely *syntax parsing*, *document analysis*, *geographic mapping*, and *annotation inferencing*.

5.3.1 Syntax Parsing

The syntax parsing is the basic reasoning process to match syntax-based keywords to a URI identifier from the Linked Open Data Cloud. The syntax parsing process is triggered by the basic concept search functionality. The GeoName service is used for place syntax parsing and the WorldHistory service is used for event and person syntax searching. For instance, when a place name of "Cape Canaveral" is given as a searching keyword, the GeoName RDF service is allocated to search for the "Cape Canaveral" string. The result of the parsing is a RDF description (see Fig. 4) including the URI identifier (<http://www.geonames.org/4149910>), the geographical information (latitude 28.45861 and longitude 80.5331), country (US), and different language spellings. These syntax parsing results are the fundamental elements which perform the further video repository query and advanced reasoning. For example, the URI identifier can be used to query videos annotated by the same URI (see Fig. 5). In the syntax parsing process, if

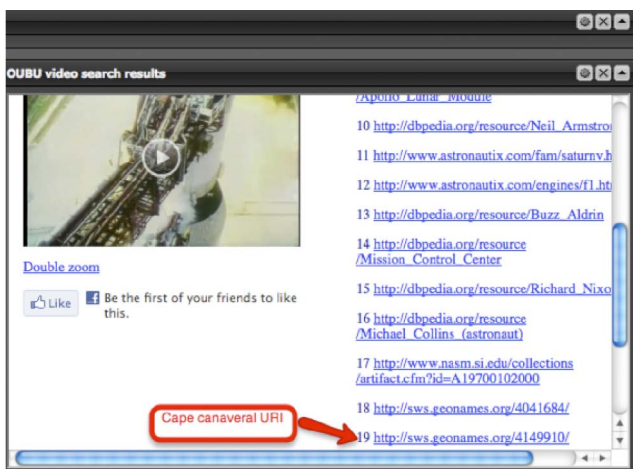


Fig. 5. SugarTube: video search results.

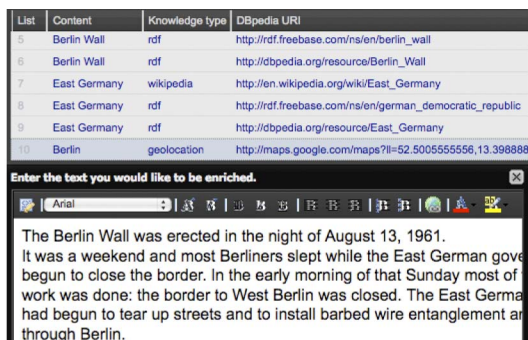


Fig. 6. SugarTube: document analyzing results.

there is more than one RDF instance found for the same syntax concept, a suggestion dialog box appears to allow users to specify which one is the target concept (e.g., Birmingham can refer to a city located in either the United Kingdom or United States).

5.3.2 Document Analysis

The document analysis process is used to analyze a document that is used to guide the study topic (e.g., the "Berlin Wall" historical topic). Typical documents are lecture notes and online webpages (including online slides). Currently, the Zemanta service is used for documentation analysis task. The analysis results are key learning points, knowledge, and concepts with their URI identifiers from the Linked Open Data cloud. For example (see Fig. 6), when a document about the "Berlin Wall" is processed, the key learning points in the document are identified as Berlin, Berlin Wall, Germany, East Germany and so on. These key points are matched to URI identifiers in DBpedia, Wikipedia, and Freebase for gaining further related educational resources.

5.3.3 Geographic Mapping

The geographic mapping process uses the Google map API to give students a geographical image to allow them to better understand the learning topic. The reasoning includes using the map information as the starting point to search for videos and other related learning resources, as well as parsing syntax or document analysis results to get the map. Taking the previous "Cape Canaveral" example, the latitude and longitude, which are gained by parsing the RDF results, are used to locate "Cape Canaveral" on the Google map (see Fig. 7).



Fig. 7. SugarTube: geographic reasoning result.



Fig. 8. Linked videos from different educational resources.

5.3.4 Annotation Inferencing

The annotation inferencing process uses the tree-structure advantages of the ontology-based semantic annotations. The annotation class definition has the properties of *rdfs:subClassOf*, *owl:sameAs*, and *rdfs:seeAlso*. For example, if <http://dbpedia.org/page/UnitedKingdom>, *owl:sameAs* <http://www.freebase.com/view/en/unitedkingdom>, then any videos annotated with either of these two URIs will be related to the other. By using the annotation reasoning process, the searching results are more accurate and widely covered. Although different video resource providers may use different Linked Data vocabularies to annotate their videos, they are linked together as search results through the SugarTube browser (see Fig. 8).

5.4 Data Mashup

Fig. 9 displays the mashup results for a video search request. It consists of four main sections:

- the event timeline section (left bottom) in which a list of history events related to the search concept is displayed and sorted by time;
- the OU annotated video displaying section (middle) that allows users to watch videos, view the annotation data and share the video with friends;
- the related knowledge section (right top) that includes the dereferenciable data links from the web (via Sindice), the geolocation Google map (data come from GeoName), and related learning resource metadata from the OU linked open data sets, and
- the related videos and TV programs section (right bottom) that contains all potentially related videos and TV programs metadata from YouTube, OpenLearn, and BBC programs.

6 LESSONS LEARNED

Currently, Annomation and SugarTube serve as the testing prototypes to the OU's history course teams and their students. Because they focus on two different user groups, an overall evaluation rate for the whole platform is determined by aggregating the two separate evaluations. We organized two evaluation sessions with different user groups, namely Experts and Tutors Evaluation Group (ETEG, 15 evaluators) and Students Evaluation Group (SEG 25 evaluators). The ETEG focuses on Annomation evaluation and the SEG focuses on SugarTube evaluation.

The members of ETEG all use eLearning systems on a daily basis for teaching distant learning students. In addition, three of them have experience of using textual tools for annotating the video learning materials. The SEG includes 18 female and seven male students from ages 18-28 who are studying part-time undergraduate history courses at first year level. None of the students had any experience of using professional educational video searching tools before but often use Google or Yahoo when searching online.

The evaluation process includes four steps:

1. Demonstration. For ETEG, we used one video as an example to show the annotation functionalities that use different Linked Data resources and web services. For SEG, we demonstrated how to use SugarTube with both basic concept search and advanced search (See Section 5.2).
2. Practice. Two practice tasks are designed. One allows ETEG to annotate a certain video and the other allows SEG to search the videos related to the topics that the ETEG annotated.
3. Evaluation. We designed two sets of tasks for evaluating Annomation and SugarTube. Each set of tasks includes simple activities and more advanced activities such as using two different URIs to annotate one concept in the video or collaborative annotation. Each task has a 15-minute limit, and we monitored each user's time spent on each of the tasks.
4. Feedback collection and analysis. We used two evaluation questionnaires to collect feedback from users for Annomation and SugarTube, inquiring about the quality, performance and usability of the

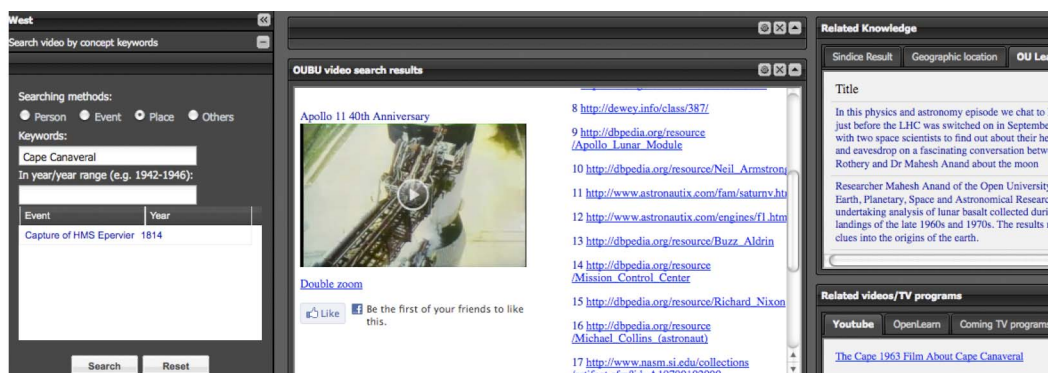


Fig. 9. Data Mashup in the SugarTube application.

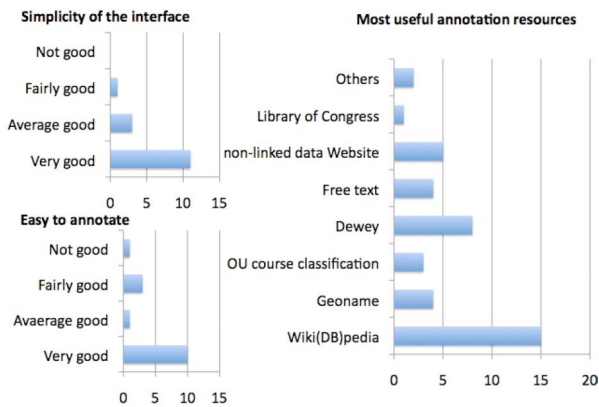


Fig. 10. Annotation evaluation results of simplicity, usability, and most used annotation resources.

tools. The evaluation methodology is to measure the time and to analyze the results of the evaluation tasks together with questionnaire answers.

6.1 Annotation Evaluation Results

The Annotation evaluation contains five tasks:

1. All members of ETEG used the “Apollo 11 40th Anniversary” video. First, asking them to use free text or any references they would like to use to annotate the historical people in the video stream. Second, asking them to use DBpedia or Wikipedia URI to identify the historical people in the video stream.
2. Using the same video to try to find the historical events behind this video and annotate them. To do this, they should use the mode option to correctly identify if the event is clearly introduced in the video stream, conversation or the audio stream.
3. Using all different Linked Data suggestions from the suggestion panel to annotate the same video that is relevant to the “Cold war” class (at least three annotations).
4. Trying to find another video that is related to the “Cold war” class by searching for the Linked Data annotations.
5. Asking people who are sat next to each other to annotate the 2 minute stream “Woods/East Berlin” video together, first, monitoring whether they both annotate the same items in the video; second, to check if they used the same Linked Data URIs for the same annotations; third, if the same items are annotated by different Linked Data, to see if they can go through the link to find each other. Finally, to check if they can correct each other or get agreement to delete or keep the duplicated annotations.

After the evaluation, we provided an Annotation evaluation questionnaire which consists of a rating for interface simplicity and usability, a rating for the quality and accuracy, identifying the most used annotation resources, identifying the most used annotation terms, and comments on using Linked Data technologies.

Fig. 10 shows that 11/15 users thought the Annotation interface is very simple to use and 10/15 users believe it is easy to find the correct annotations to use, while the questionnaire shows that users prefer to use Wikipedia or

DBpedia as annotations, which is not surprising due to the high recognition rate of Wikipedia. However, the OU course classification vocabularies are used surprisingly rarely.

The most interesting elements to be annotated are person (12 votes), place (11 votes), and event (11 votes) that exactly match the basic concept search functions provided by the SugarTube. The most common view from the ETEG evaluation group (14/15 users agreed) is that the Linked Data-based annotations are much more accurate and explicit than other free-text-based annotations and much more scalable than domain ontology-based annotations.

Another important evaluation aspect is the performance. It is mainly evaluated by analyzing the time spent on completing the evaluation tasks. The analysis shows that most users can complete the simple annotation tasks in under 3 minutes and complex tasks within a 15-minute limit. There was only one failure report about the conversation mood annotation task (lacking knowledge of the topic).

By asking for comments regarding the answers to the questionnaire, the two major lessons have been learned:

1. The discrete annotation points in the timeline of the video stream cannot tell the whole story about the video in order to understand which courses benefit from it. Therefore, most of the annotations use time durations on the video stream instead of annotating particular time points.
2. It is sometimes hard to decide which Linked Data vocabularies should be preferred and how many different annotations should be applied to one annotation element. Therefore, a guideline for the annotation process and descriptions about the capabilities of each different Linked Data vocabulary should be provided for the users.

6.2 SugarTube Evaluation Results

Whether students think the SugarTube can help their studies is the most interesting part of our evaluation task for SEG. The SugarTube evaluation tasks contains:

1. Using the basic search functions to find as many as possible (no more related new video can be found) videos that related to “Cold war” topics and were stored in OU video repository. We examined the quantity of the found videos.
2. Using the place search function and enter “Cape Canaveral” to search for related videos. Go through all video resources from different video search providers to identify at least five videos that relate to the “Moon landing” or “Apollo 11” topics.
3. Using the person search function and enter any person’s name that you believe is related to “Cold War” class and identify at least two videos from different resources and two URIs that describe either the person you searched for or “Cold war” related topics.
4. Using the map search function to search for videos and information related to “Berlin” in “Cold War” topic (at least five related resources need to be identified).
5. Taking a particular text content from a lecture note that is used for the “Cold war” class to search the

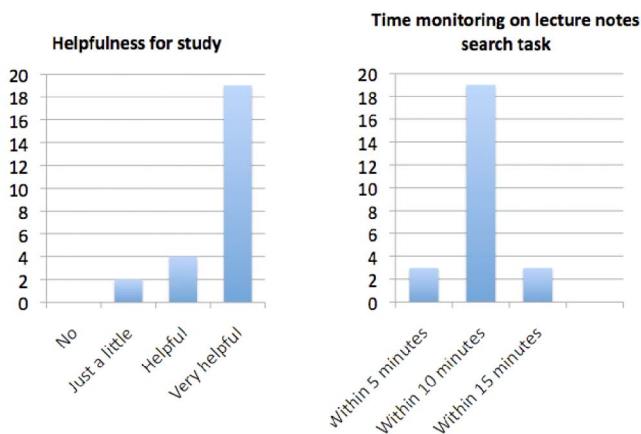


Fig. 11. SugarTube evaluation results of helpfulness and time spending on the lecture notes search task.

related and useful resources to prepare the class based on the highlights in the lecture note.

The first chart in the Fig. 11 shows that 23/25 students believe SugarTube is “very helpful” or “helpful.” Only 2/25 students voted for “a little helpful” and no student thought it is not helpful at all. This is an encouraging message for us.

By monitoring how long it takes the students to identify all the related videos and useful information for a history lecture note (500 words), we found that most of the students can finish this task within 10 minutes (see second chart of Fig. 11) by choosing to use the document analysis function. Consequently, students unanimously agree that the document analysis is the most useful function for their course preparations (basic concept search function is second, see the first chart in Fig. 12).

The videos or data voted most useful come from the OU linked open data set, Openlearn, and Wikipedia/DBpedia (surprisingly, YouTube resources and TV resources are the most unpopular data, see the second chart in Fig. 12).

The most important lesson learned from the evaluation at this stage is that students are more interested in the data that comes directly from the education-oriented services rather than social information websites such as YouTube.

The other parts of SugarTube evaluation questionnaire consist of the rating of the usability, quality, and accuracy of the tool. 20/25 students voted the usability as “very good,” 22/25 students voted the quality as “very good,” and 24/25 students voted the accuracy as “very good.” The major concern is the response time of some searches at runtime. As the SugarTube is a search tool that invokes different Linked Data services at the same time after search request is received, services’ response time are different because of the quality of their own services and servers’ runtime workload. This is a tradeoff between the quality and the accuracy. Since we invoke different Linked Data services at the runtime, the newest information and various data are found, which reflects the high accuracy satisfaction rate in the survey.

Note that since both tools are still in prototype testing, there is still much work to be done to integrate them to the current OU distance learning systems and processes. The limitation of our evaluation is that we cannot evaluate how much the SugarTube can improve the tuition without

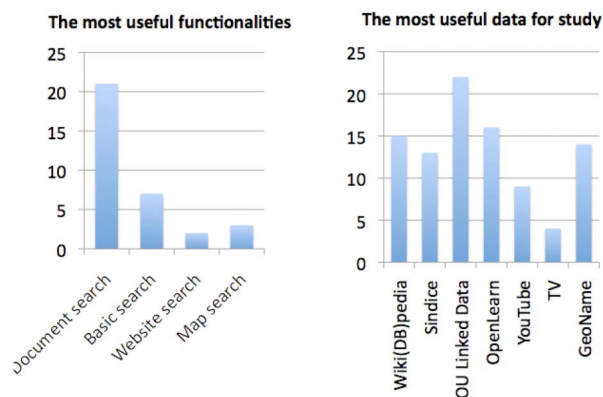


Fig. 12. SugarTube evaluation results for most useful functionality and data.

applying it on live course teaching and examination processes.

7 CONCLUSION AND FUTURE WORK

This paper illustrated the Annotation and the SugarTube platform that uses Linked Data technologies to semantically annotate and search educational video resources from the Open University video repository and link the videos to other educational resources on the web.

In the semantic annotation process, 1) an annotation ontology is defined to support Linked Data annotations; 2) dynamic annotation URI suggestions are fully supported by integrating Linked Data Services into the Annotation interface; and 3) collaborative functionalities are implemented to enhance the teamwork capability.

In the semantic search process, the search methods are based on the data retrieved through Linked Data Services and URIs, which links different resources together to enrich the original video search results. SugarTube shows that e-learning resources distributed across different educational organizations can be linked together to provide more value-added information.

The contributions of introducing Linked Data technologies to annotate and browse multimedia educational resources are summarized as follows:

1. The initial learning content management systems do not need to be changed but only adding the extra semantic annotations to the existing data, then the learning resources will be linked and become parts of the Linked Data Cloud.
2. Annotations are accurate and free of spelling errors, ambiguity, and multilinguality issues.
3. The semantics of the annotations are processable by machine, which fosters the accuracy of searching and collecting related learning resources.
4. The educational resources from different educational institutions are shared, reused, and semantically connected.

Further research work will integrate a context-aware annotation suggestion technique [32] into the Annotation application to speed up the annotation process. Furthermore, it is worth adding more Web 2.0 functionalities to the SugarTube browser to support better educational resources

sharing between users. It is also important to integrate Semantic Web Service technologies, such as dynamic service discovery, invocation, and orchestration, to the applications for better usage of a wider range of the available Linked Data Services.

ACKNOWLEDGMENTS

This research was partly funded by the European Commission's 7th Framework Program SOA4ALL project, NoTube project, and the Open University's Semantic Media Group.

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