Semantic Search on Cross-Media Cultural Archives

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Summary. With the emergence and development of semantic web, traditional archive service meets a new challenge to provide more intelligent and interactive services for web users. To take good advantage of semantic web technologies, in particular ontology and semantic inference, this paper proposes a semantic search portal for cross-media cultural archives involving document, image, audio and video. With such semantically-enhanced search portal, implicit multimedia archives can be retrieved under the support of ontology modeling and semantic reasoning. Furthermore, the retrieved cross-media archives can be semantically navigated and repacked in a more meaningful and integrated way.

1 Introduction

Semantic web, invented by Tim Berners-Lee a half decade ago, aims to provide a new generation of web with machine understandable meanings [1]. With the starting point of semantics rather than syntactics, information can be organized and described with a fully-fledged schema like ontology. Based on the comprehensive information description, semantic web supports reasoning with logic foundation, in particular description logic. Furthermore, due to the agent technology, more intelligent and interactive services can be realized.

Besides theoretical studies on ontology, logic and agent, semantic web come forth with many domain scenarios to further demonstrate its advantages. Several domain-oriented ontolgoies have been constructed to achieve semantic resources organization and retrieval, such as DOAP[1] (Description Of A Project) for open source projects, SIOC[2] (Semantically-Interlinked Online Communities) and FOAF[3] (Friend Of A Friend) for social networks. Besides those domain-specific ontolgoies, there are some generalized or so-called upper-level ontolgoies crossing different domains such as Dublin Core, WordNet, SHOE

[1] DOAP, http://usefulinc.com/doap/
[2] SIOC, http://sioc-project.org/
[3] FOAF, http://www.foaf-project.org/

(Simple HTML Ontology Extensions) and SKOS (Simple Knowledge Organisation System). However, though with so many existing ontology construction works, there is still less study on real-world semantic applications, especially for semantically-enhanced multimedia services. Related to multimedia, we have to mention here is some highlight EU semantic projects referring to the audio domain, such as SIMAC[4], EASAIER[5], SMaRT[6]. Different from those projects focusing on media ontology construction, our work mainly emphasize the cross-media archives searching service with the semantic cornerstone.

Based on the real world and valuable cross-media cultural archives, this paper proposes semantic search to validate the semantic advantages on boosting archive search services. The paper proceeds as follows: Section 2 provides an integrated semantic model; Section 3 presents the ontology-enhanced culture archives modeling; Section 4 shows how semantics can achieve the intelligent search services for culture achieves; and finally the conclusion is discussed.

2 Semantic Model for Cultural Archives

Hereby, we briefly analyze the semantic description requirements for cultural archives. Furthermore, we propose an integrated semantic model with the support of providing more intelligent and interactive archive search service.

2.1 Semantic Description for Cross-Media Cultural Archives

Ontology plays a crucial role in semantic web[5][7], and in archive modeling either. Cross-media culture archives should be semantically described to support the subsequent intelligent archive search service. We take traditional Dunhuang culture, with two thousand years of history, in west China as our use case [2]. For simplicity but efficiency, there are only five core concepts in our ontology model, i.e. MEDIA (the cross-media characteristics for cultural archives, involving document, image, audio, video), DYNASTY (embodying the individual history of each archive, such as the thriving Tang dynasty in ancient China), CAVE (there are many cultural caves, which store abundant culture legacies comprising frescos and sculptures etc.; of course, the cave itself is also a kind of culture legacy), CONTENT (the significant concept embodies the cultural and artistic characteristics, such as the frescos and sculptures mentioned before); finally, the most important concept for archives is DATA (which models all concrete culture archives in a comprehensive concept).

We have developed an ontology tool for cultural archives modeling, shown in Fig.1. In the figure, the five red rectangles express the five core concepts discussed before; whilst, the green small ones are some example instances belonging to those concepts respectively.

[4] SIMAC, http://www.semanticaudio.org
[5] EASAIER, http://www.easaier.org/
[6] SMaRT, http://www.k-space.eu/

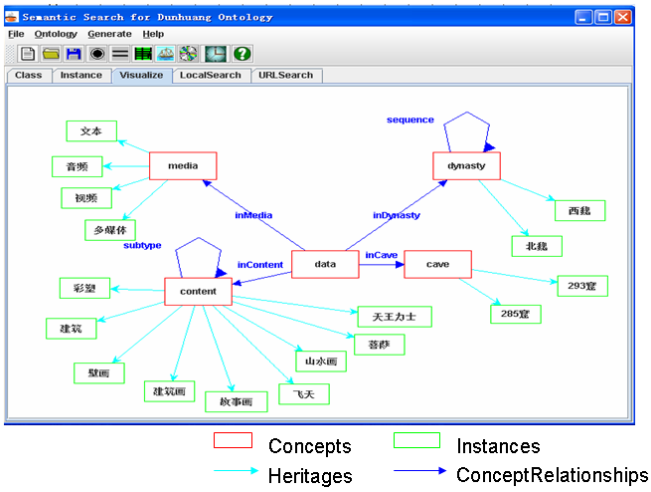

Fig. 1. The Snapshot for Cultural Archives Ontology Visualization

2.2 Semantically-enhanced Service Model

From previous semantic schema of culture archives, we can see plentiful information among archives. How to provide those information with fully-fledged semantic description? Furthermore, how to achieve more interactive and intelligent service? To answer them, we propose an integrated semantic model, including archives modeling (both concept and instance level), storing, and semantic searching. The original model shown in Fig.2 is domain-independent, and can be adapted to other domains like research community [3][4].

There are four layers in the model, including "semantic storage", "semantic annotation", "semantic search" and "user interface". In addition, "semantic inference" is a vertical component to further infuse semantic technologies. More details about this domain-oriented but domain-independent semantic model can be found in [4]. In this paper, the emphasis is the adaptation of such model for culture archives to attain more intelligent search services.

3 Semantically-enhanced Cultural Archives Modeling

From the model in Fig.2, there are three core issues have to be considered referring to cultural archives modeling, i.e. archives ontology model, supporting semantic annotation and storage strategy.

Conceptualized Model To achieve comprehensive schema for cultural archives, we apply previous semantic scenario. As shown in Fig. 1, there are five core concepts should be modeled. In consist with the ontology structure, all the relevant data should be modeled, including data-type properties

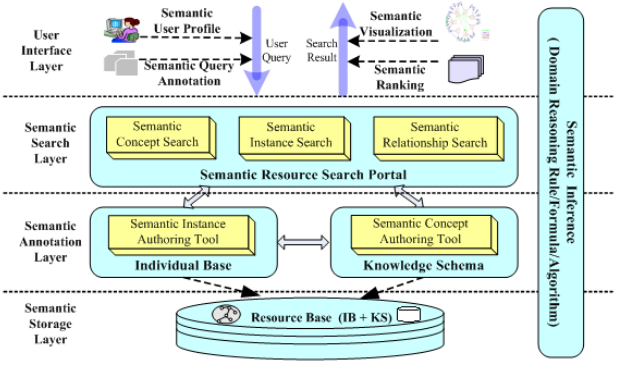

Fig. 2. The Integrated Semantic Model for Cultural Archives

and object properties [7]. In the meanwhile, the schema of their instances, even the storage mechanism, ought to be considered seriously. The detailed storage strategies will be discussed in the following section.

Semantic Annotation Semantic annotation for multimedia content has been identified as an important step towards more efficient retrieval of multimedia data [9] [8]. Basically, we apply authoring tools for semantic annotation, involving two kinds of archive annotation interfaces (shown in Fig. 3 a, the top-left is semantic annotation about basic archives information, whilst the right-down is for annotating semantic relationships with other instance resources).

Semantic Storage There are two kinds of information about cultural archives need to be stored, namely concept information and concrete instances. For concept, we mainly take OWL files as the serialization layer as only five core concepts and rich semantics; whilst, the relational database is more advisable for the abundant real world cultural archives in instance level.

4 Intelligent Search for Cross-media Cultural Archives

With the essential semantic model and annotation preconditions, more intelligent services as semantic search can be attained on cultural archives. Besides basic semantic search, we further highlight semantic inference to enhance search service with more intelligence, which is our distinguishing feature from some existing semantic search studies on multimedia data [10][11].

4.1 Semantic Search for Archives

As shown in the semantic model and different from traditional search engine, the query-keys input to search portal can be denoted with certain semantic information, for example a concrete concept. With this semantic denotation,

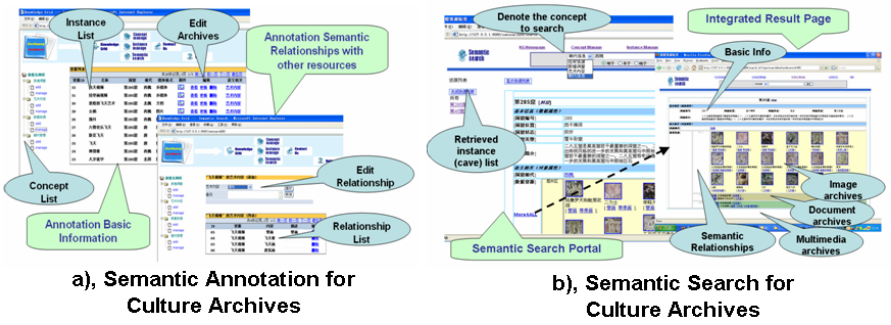

Fig. 3. Snapshots for Semantic Search on Archives

the query results can be profoundly-repacked with the inward semantic schema of the concept, including basic information and semantic relationships with other concepts.

In stead of listing search algorithm, we address the search portal more clearly by a concrete search example. When users query Cave285, the portal feedbacks all the relevant information in the CAVE schema asserted before. Firstly, the basic information of the 285th cave includes the cave number, name etc. and some beyond description information like protection-level; secondly, semantic associated information must be extracted. There are two main associated information for CAVE, i.e. DYNASTY and DATA. For Cave285, there is only one dynasty referred, namely the building time in the XIWEI dynasty. However, many other caves are concerned with more than one dynasty, including the first-building time and some restoring milestones in other dynasties. About DATA instances in Cave285, they are the core elements as cultural archives. To embody the cross-media features of cultural archives, the archives are demonstrated in three main categories, namely document, image and multimedia (including audio and video). Furthermore, every concrete archive (DATA instance) should contain relevant semantic information about its belonging CONTENT instance (such as *Murals* or *Sculptures* etc, even their inherited sub-contents, such as *Feitian* and *Pushan*). The previous Fig.3 b) is the snapshot for the 285th cave example. The left is about semantic search portal, whilst the right (navigated from the left) is the integrated result page for a certain retrieved cave.

4.2 Inference-enhanced Search Service

Besides semantically-enhanced (or rather ontology-supported) resource description, another main advantage of semantics is semantic inference with logic foundation. With inferences, more implicit information can be extracted, and the search results can be more comprehensive and rational. As shown in Fig. 2, the vertical inference mechanism is attained gradually by reasoning rules, formulas and detailed algorithms. According to the space limitation, we do

not discuss much details about inference, but mention two representative reasoning rules and one formula having been concerned in our implementation.

Rule 1 *the transitivity of subContent property for the CONTENT instances*
$< c_1, subContent, c_2 >, < c_2, subContent, c_3 > \Rightarrow < c_1, subContent, c_3 >$
$< data, isContent, c_2 >, < c_1, subContent, c_2 > \Rightarrow < data, isContent, c_1 >$

Rule 2 *the transitivity of DYNASTY sequence*
$< dyn_1, after, dyn_2 >, < dyn_2, after, dyn_3 > \Rightarrow < dyn_1, after, dyn_3 >$
$< dyn_1, before, dyn_2 >, < dyn_2, before, dyn_3 > \Rightarrow < dyn_1, before, dyn_3 >$

Formula 1 *calculate the archives belonging to CONTENT instance c*
$getArchives(c) = annotatedArchives(c) + subContentArchives(c)$
$annotatedArchives(c) = \{arh_k\}, \forall k < arh_k, isContent, c >$
$$subContentArchives(c) = \begin{cases} \cup getArchives(c_k), & \forall k < c, subContent, c_k > \\ \emptyset, & with\ no\ tuple\ above \end{cases}$$

5 Conclusion

In the paper, we propose a semantic model providing semantic search on cross-media cultural archives. With the analysis and implementation of this model, especially the support of semantic inference, we can validate the advantages of semantic web technologies for traditional multimedia services, which can further provide more intelligent and interactive archive search services.

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