A METADATA MODEL FOR REPRESENTING TIME-DEPENDENT INFORMATION IN CULTURAL COLLECTIONS*

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Temporal metadata are significant for the management of cultural collections since every object has a historical reference. The goal of this paper is to enrich collection-level descriptions with time representation and management capabilities. We obtain this by deploying a formalism called Multidimensional RDF, which enables the RDF model to represent in a compact way multiple facets of information.

1 Introduction

It is widely known that cultural collections contain resources of great worth for the national conscience and the intellectual life of a society. Digitization projects related with folklore collections are very important because they contribute to the exposition of cultural material to a wide audience through the web and to the preservation of the cultural features. A digital cultural collection needs to be functional for all the groups of users and easily retrievable by them offering various access points. So two main requirements exist for the cultural information management and dissemination process: a) the material

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should preserve its unique characteristics and b) the semantic context of the collection and of its objects should be expressed clearly. Although much attention has been given to the cultural objects description, metadata models that describe compound cultural collections as entities are strongly needed [1].

A significant parameter for the development of descriptive and administrative collection-level metadata models is the concept of time. Each cultural object refers to a historical period and the procedures of material study and documentation are based on that historical reference. It is quite useful to keep track of the changes of a “habit” or a “tale” through the time and how these changes affected the life of specific group of people. Moreover time representation and manipulation is important not only for the study of the semantic context of the cultural objects but also for the collection management. The content of cultural collections evolves and changes constantly during the time, so it is strongly needed to keep information concerning the time that changes occur. However, only a few papers attempted to address the problem of time representation in cultural collections [2,3,4].

In this paper we deal with the issue of representing and manipulating time-dependent information in collection-level cultural metadata. The main contribution of our work is that we present an extension of the RDF model called Multidimensional RDF (MRDF). The proposed extension is used in this paper to enrich a metadata application profile, developed for the collection-level description of cultural materials, with the ability of time representation and manipulation. Our approach is motivated by the large collection of the Folklore Department of the University of Athens, Greece, which is consisted of varied types of material such as text written on different kinds of materials, still images, photographs, 3D objects, sound recordings, maps or even digital material.

The rest of the paper is organized as follows: In Section 2, we present our metadata model and discuss the cases in which the time deployment is necessary for the cultural collections management. In Section 3 we present the Multidimensional RDF formalism. In Section 4, we demonstrate how time can be incorporated into our metadata model using the MRDF formalism. In Section 5 we show how we can obtain temporal snapshots of the MRDF graph which hold under specific time points. Finally, in Section 6, we discuss the results of the paper and give hints for future work.

2 Collection-level metadata and the concept of time

Collection-level descriptions are of crucial importance as they help users to decide whether the collection is of their interest and to navigate and retrieve efficiently its heterogeneous cultural content. Therefore a data model for collection description should address the interests of a wide audience and must cover all the categories of users (researchers, students, teachers, pupils, adults, teenagers etc.). The main requirements for the design of a metadata model for cultural collections are [5]: (a) it should express both the subject coverage of the resources and all the details of their creation, (b) it should represent the structure of the collection and how it has been organized into subcollections, providing information about every structural level, (c) the model must also express the semantics of the material and to reveal its evolution through time. It is essential to show how objects, morals and beliefs have been changed and how they are reflected to our present life. Finally the proposed data model needs to be interoperable with other models.

2.1 An application profile for folklore collections

Concerning the collection-level descriptions the most known metadata standards are the Dublin Core Collection Description Application Profile (DC CD AP) [6] that has been developed recently, the Research Support Libraries Programme collection description schema (RSLP) [7] and the International Standard for Archival Description (ISAD(G)) [8]. Moreover a variety of collection level application profiles has been generated such as the Alexandria Digital Library (ADL) metadata schema [9], Renardus collection level description [10], Riding and Agora experience [11] and many other that have been implemented to serve specific user needs and project requirements [12].

We argue that the above metadata schemas cannot fully satisfy the requirements, that we mentioned before, for describing a compound collection like in our case. For example, none of them provides elements to encode any information about the purpose of the collection or the meta-metadata description of the items. The term meta-metadata refers to the metadata standards that are used to describe the varied digital objects of the collection. Specifically, DC CD AP does not support the encoding of information for the legal status of the collection but supports information about the audience in contrast with ISAD(G). On the other hand RSLP does not support the encoding of information neither about the audience nor about the legal status.

Having the above limitations in mind we propose [13] an application profile which considers as a core metadata schema the DC CD AP enriched with elements from the ISAD(G), RSLP, Alexandria Digital Library metadata model (ADL) and Learning Object Metadata (LOM) [14]. The elements of the proposed schema and their origin are given in Figure 1. In particular we have added the refined term *table of contents* of the Dublin Core schema which in combination with the element *abstract* of DC CD AP can be used to describe thoroughly the contents of the collection or subcollections. Also we have added from the Dublin Core schema the element *relation* with all its corresponding refined terms in order to describe other types of relations that might exist such as: whether the collection has another format or is referenced by another source. Moreover the element *date* with all the refined terms has been added from the basic Dublin Core schema to enrich the collection description with time-dependent information.

Descriptive metadata	
Title (dc cd ap)	Alternative title (dc cd ap)
Identifier (dc cd ap)	Temporal coverage (dc cd ap)
Spatial coverage (dc cd ap)	Subject (dc cd ap)
Abstract (dc cd ap)	Accumulation date range (dc cd ap)
Source (dc)	Audience (dc cd ap)
Collector of objects (dc cd ap)	Note (rslp/ isad(G))
Accrual Status (dc cd ap)	Language (dc cd ap)
Scope/ purpose (adl)	Table of contents (dc terms)
Custodial History (dc cd ap)	
Administrative metadata	
Medium (dc terms)	Contributor (dc)
Type (dc cd ap)	Date:issued, available, created (dc terms)
Rights (dc)	Legal Status (isad(G))
Owner (dc cd ap)	Location (rslp)
Size (dc cd ap)	Access rights (dc cd ap)
Metadata schema (adl)	Metadata mapping (adl)
Structural metadata	
Super-Collection (dc cd ap)	Associated collection (dc cd ap)
Relation (dc terms)	Sub-Collection (dc cd ap)
Structure (lom)	

Figure 1. The proposed application profile.

Furthermore the element *rights* from the basic Dublin Core schema as well as the element *legal status* of the collection from ISAD(G) have been added since there is need to keep information for the protection of the content of the collection. The ADL element *scope/purpose* is considered important to specify for which purpose the collection has been created or how it will be used. Moreover, two elements have been added to our application profile namely the element *structure* borrowed from LOM to denote the structure of the collection (hierarchical, linear or networked) and the element *location* taken from RSLP which is used to provide location information for both the physical and digital collection.

Also we have added two other important elements used to encode metadata information (metadata schema & mapping) taken from the schema of Alexandria Digital Library collection. These elements describe the metadata schemas that are used for item-level description of the collection resources and the mappings between them. This kind of information is valuable for the description of collections consisted of other subcollections of heterogeneous resources since it can specify exactly which metadata standard has been used for the documentation of each subcollection.

Our model is implemented using the RDF/XML model [15] due to its suitability to express rich semantics and to enhance interoperability between metadata models. As an example, a fragment of the proposed metadata model is given in Figure 2. The model provides information about the collection as

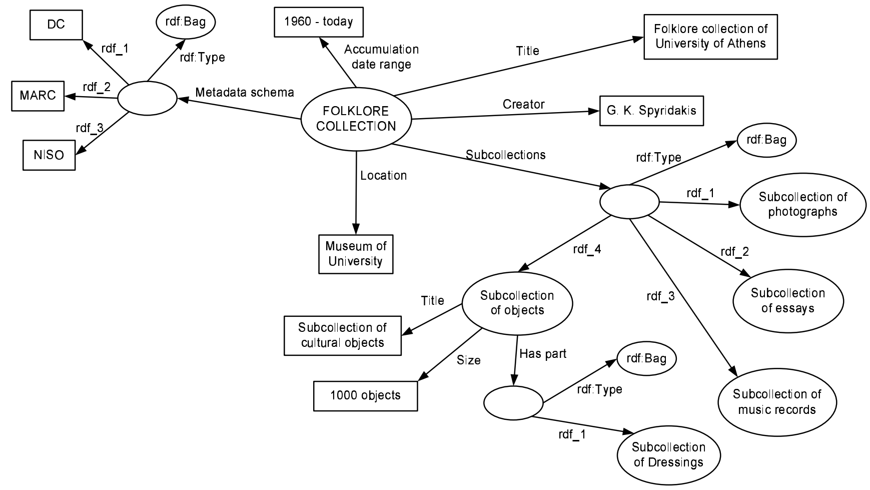

Figure 2. An RDF graph for collection level description.

a whole, such as the title, collector, location, time period that the material was accumulated, and the metadata schemata of each subcollection. The particular collection consists of four subcollections each one comprising different types of material (text, objects, photographs and music records) and therefore described by different metadata schemata, DC, MARC, and NISO(MIX) [16].

2.2 The need of time representation

Time representation and tracking are essential for cultural heritage collections mainly for two reasons: Firstly they provide the ability to depict the cultural heritage evolution. Cultural heritage content evolves dynamically and it is significant to study the way of living of specific groups of people through time. Secondly they provide significant information for the reasonable management of the cultural collections per se. In general, time encapsulation in cultural heritage collections concerns the evolution representation of both the content and the collection.

Content: The cultural material is "alive" because it may alter over time. For example the morals and habits of a specific historical period are preserved up to now but with variations. Although the most metadata standards offer some elements to encode temporal information related to the collections coverage like: *coverage_time* (lom), *temporal coverage* (rslp, dccdap, adl) etc., these metadata elements do not provide any information when the content of the collection has changed; furthermore they cannot be used for reasoning purposes. For example in case that we have divided collections by type of object, like a “subcollection of Spoons”, there is no possibility to state that some spoons of the subcollection had being made from “wood” and that after a specific period of time other spoons that belong to the same subcollection were being made from “copper”. This change that occurred in the diary life of some people cannot be reflected in the description of the subcollection. An interesting problem that arises to this point is the difficulty to set concrete “time limits” in cultural material. For example, we may have a time interval of the form: 1750 to 19th century. Therefore we need flexible models able to deal with multiple time granularities.

Context: It is important to track the changes and actions that happen during the lifetime of a collection for administrative and preservation reasons. The source metadata standards of our application profile provide some fields that only describe when a collection was created or accumulated, such as *accumulation date range (rslp, dccdap), date (adl), date when archives are accumulated (isad), date when docs are created (isad(G))* and *lifecycle.contribute.date (lom)*. Finally some of the standards use time in terms of collection administration: *accrual status (rslp, dccdap), date of the collection that last updated (adl), update frequency (adl)*. The main goal is to show how specific events affect the status or the characteristics of a collection. For example the movement of a collection from a place to another in a particular time point affects its preservation conditions and this change should be depicted in the collection metadata.

Concluding, the concept of time could be decomposed to two orthogonal dimensions; the first dimension correspond to the historical reference of the material, while the second to the metadata management.

3 Multidimensional RDF

In the following sections we present an extension of our metadata model, which is suitable for representing time-dependent information. The proposed extension is based on Multidimensional RDF (or MRDF in short) [17], which enhances RDF with the capability of representing context dependent information (i.e. information that presents different facets under different contexts). MRDF employs a set of parameters, called *dimensions*, which are used to determine specific environments, called *worlds*, under which specific pieces of information hold.

3.1 Dimensions and Worlds

The notion of *world* is fundamental in MRDF. A world represents an environment under which RDF data obtain an essence. More specifically, a world is determined by assigning values to a set S of parameters called *dimensions*.

For each dimension d in S there exist a respective *domain* D_d, where $D_d \neq \emptyset$. A world W is considered as a set of pairs (d, u), where d is a member of S and u is a member of D_d, such that for every dimension in S there exists exactly one element in W. In Multidimensional RDF, sets of worlds are specified by syntactic constructs called *context specifiers*. Consider for example the following three context specifiers:

(a) $[colour\ in\ \{blue, green, red\}]$
(b) $[t\ in\ \{1950..1980\}]$
(c) $[region = Greece, t\ in\ \{1990..now\}]$

Context specifier (a) represents the worlds for which the dimension *colour* gets one of the values *blue*, *green*, or *red*. Context specifier (b) represents the worlds for which the dimension t gets as value an integer in the interval 1950..1980. Finally, context specifier (c) represents the set of worlds for which the (geographical) *region* is *Greece* and t gets a value in the chronological interval from 1990 to the present day (symbolized by the reserved word *now*).

Context specifiers use operators such as $=$, $!=$, *in*, and *not in* to relate dimension names to expressions specifying sets of values. If the operator is either $=$ or $!=$ then the expression consists of a single dimension value. Otherwise, if the operator is either *in* or *not in*, the expression is a set of values of the form $\{value1, ..., valuek\}$. For linear and discrete domains (as it is the case in the second and third context specifiers above) we will also use the notation $\{a..b\}$ to denote the set of all values x such that $a \leq x \leq b$.

As it is clear from the above examples, context specifiers impose constraints to the set of possible values of each dimension. In this sense, if a context specifier does not contain a constraint for a specific dimension then this dimension can get any value from its domain. As a consequence, the context specifier [ ] represents the set of all possible worlds.

3.2 Multidimensional RDF graphs

Resource Description Framework (RDF) [18,19] as proposed by W3C is based on the idea of identifying *resources* using Web identifiers (called Uniform Resource Identifiers, or URIs), and describing them in terms of simple *properties* (also called *predicates*) and property values (also called *objects*). The described resources are called *subjects*. In this way an RDF graph consists of a set of *triples* (or *statement triples*) of the form subject-predicate-object, where the subject and the object are nodes of the graph and the predicate is the label of an arc that connects the subject with the object. In RDF a triple is considered to hold under every context.

Multidimensional RDF is an extension of RDF based on the idea that the existence of a specific triple in an RDF graph, as well as the value of the object in a specific triple may depend on the values of a set of dimensions i.e. on a specific world. Contrary to the conventional RDF, in multidimensional RDF we may have multiple resources as objects of the same property under different worlds. We call these resources *facets* of that object. In Multidimensional RDF, context specifiers are used to determine the circumstances under which RDF triples are considered to be present or not in a graph.

In particular, in MRDF, besides the conventional RDF nodes, there is also a new type of nodes called *multidimensional nodes*. As a consequence, we also have two types of arcs, namely the *statement arcs* and the *context arcs*. Statement arcs are of the form (r, p, b) where r is a node representing an RDF resource, p is a property, and b is either a conventional RDF node (representing a resource or a literal) or a multidimensional node. Context arcs are of the form (m, c, o), where m is a multidimensional node, c is a context specifier and o is a conventional RDF node (representing a resource or a literal). Every context arc departing from a specific multidimensional node, points to an alternative property value (i.e. object), which holds under the worlds described by the corresponding context specifier. A statement arc leading to a multidimensional node m along with all context arcs departing from m, constitute a *multidimensional statement* (or *MRDF statement*). Figure 3 presents the structure of a multidimensional statement. Notice that in an

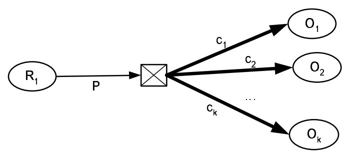

Figure 3. An MRDF statement.

MRDF-graph thin lines represent statement triples while thick lines represent context triples.

A restriction imposed on MRDF graphs is that for every multidimensional node m in the graph there should be at least one context triple departing from m. An MRDF graph G is said to be *deterministic*, if for every multidimensional node m in G, the context specifiers of all context triples departing from m are mutually exclusive each other (i.e. they represent disjoint sets of worlds). In this paper we consider only deterministic MRDF-graphs. Finally, an extension of the triples syntax as well as of the XML/RDF syntax has been proposed in [17] for recording MRDF graphs. A detailed description of the semantics of MRDF is presented in [17].

4 Incorporating time in the metadata model using MRDF

In order for our metadata model to become suitable for representing time-dependent information, we use the MRDF formalism with two orthogonal (i.e. independent of each other) time dimensions. The first time dimension, refers to the management of the collection (see the notion of *context* in Subsection 2.2 for details) and is denoted by the letter t. The second time dimension refers to the *content* of the collection (see also Subsection 2.2) and is denoted by v. For simplicity reasons the domain of both dimensions is the set of integer values representing years. However, more refined domains can be employed representing different time granularities (such as days, time, seconds etc).

It should be noted that time dimensions can be applied to all elements of the proposed application profile. However, due to the unique characteristics of folklore collections the encapsulation of time dimensions make more sense to be employed in specific elements of the application profile, such as *Metadata schema, Medium, Legal Status, Owner, Location, Size, Access rights, Sub-Collection, Table of contents.*

An example of how to use the proposed time dimensions to encode temporal information in our metadata model is shown in Figure 4. Observe that the

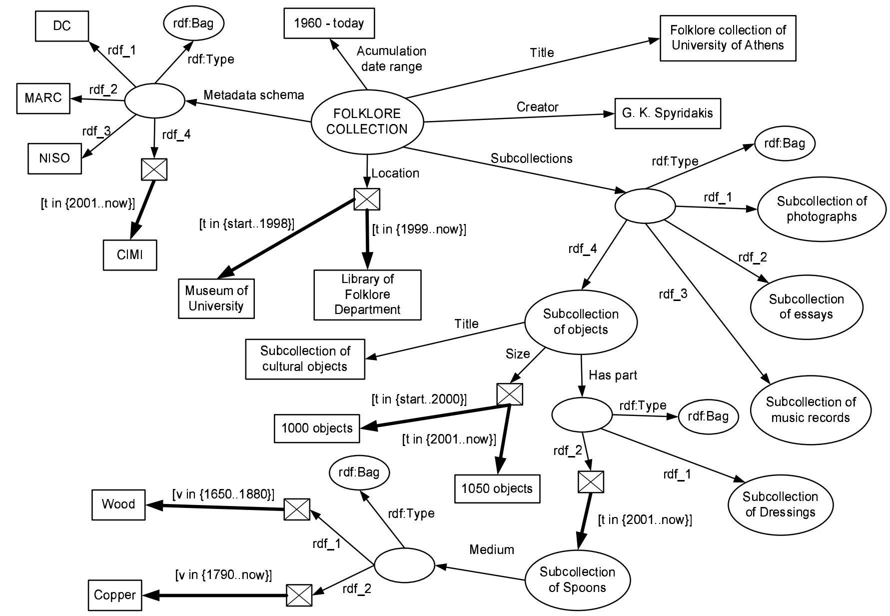

Figure 4. A Multidimensional RDF graph for the cultural collection metadata.

element (property) *Location* has two possible objects. The first one has the value "*Museum of University*" and is valid for the time interval $\{start..1998\}$ while the second object value is "*Library of Folklore Department*" and is valid for the time interval $\{1999..now\}$. This representation provides information that the collection was kept in the Museum of University from *start*[a] till 1998 and then, in 1999, it moved to the Library of Folklore Department where it is

[a]The reserved word *start* is used here to represent the time at which the collection was first created.

kept since then. There are three more cases in which the dimension t is used in Figure 4. The first case concerns the property *Metadata schema* where the CIMI schema was added in the bag container, denoting the schemas that are used for the collection description, in 2001. The second case refers to a new subcollection, named *Subcollection of Spoons*, which is present in the collection only during the time period $\{2001..now\}$. The third case refers to the element *size*. The value of this element is 1000 during the interval $\{start..2000\}$ and 1050 from 2001 till *now*. Notice that this encodes the fact that in 2001 the new subcollection named *Subcollection of Spoons* (which obviously consists of 50 objects) has been added to our collection.

It is also interesting to observe in Figure 4 the use of the time dimension v in the object of the property *Medium* of the *Subcollection of Spoons*. Now the time dimension relates to the content of the collection. The medium from which the objects of the *Subcollection of Spoons* were made was *Wood* during the period from 1650 to 1880, while the same objects were made by *Copper*, during the period 1790 to *now*.

It is important to mention that the time dimension t proposed above presents many similarities to the notion of *transaction time* used in temporal databases [20]. On the other hand our dimension v is similar to the notion of *valid time* of temporal databases. Recall that transaction time refers to the time that a piece of information is added to a database while valid time refers to the time that a piece of information holds.

5 Obtaining RDF snapshots from the Multidimensional metadata model

A Multidimensional RDF-graph can be seen as a compact representation of a set of (conventional) RDF-graphs each of them holding under a specific world. It is thus interesting for our model to design a procedure to obtain conventional RDF graphs that correspond to specific worlds.

Given an MRDF-graph G and a specific world w a conventional RDF graph, holding under w, can be extracted from G through the following procedure called *reduction*:

1. All context arcs (m, c, r) for which the world w does not belong to the worlds represented by the context specifier c are removed.

2. For the remaining graph do the following:

   (a) For every pair of triples of the form (r_1, p, m) and (m, c, r_2), where m is a multidimensional node, add an arc corresponding to the triple (r_1, p, r_2).

   (b) Remove all statement arcs of the form (r, p, m), where m is a multidimensional node. Remove also all context arcs.

(c) Remove all multidimensional nodes and all nodes for which there is no ingoing or outgoing arc.

(d) If the MRDF graph is a rooted one (i.e. if some nodes play the role of entry points to the graph), then eliminate all subgraphs which are not accessible from any root node.

As an example of applying the reduction procedure suppose that we want to find the snapshot of the MRDF graph of Figure 4 holding under the world $w = \{(t, 2002), (v, 1700)\}$. Concerning the meaning of this operation it is easy to see that we want to find the snapshot of the collection as it was at the year 2002, and including only content information that refers to the year 1700. The snapshot corresponding to the world w is shown in Figure 5.

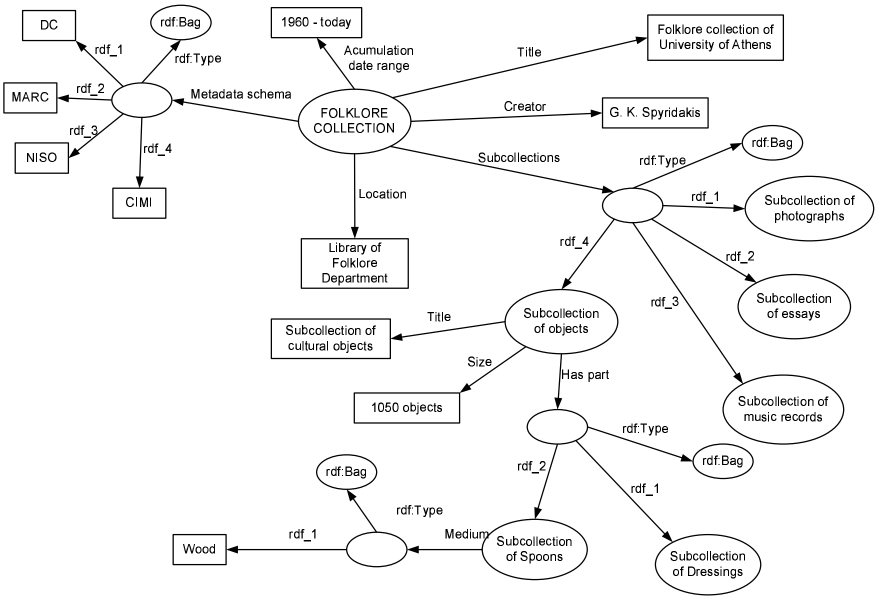

Figure 5. A temporal snapshot of the metadata model of Figure 4.

Notice that in the snapshot shown in Figure 5 the value of the element *Location* is "*Library of Folklore Department*" as this is the facet of the object of this element holding at $t = 2002$. Moreover, the *Subcollection of Spoons* appears in the graph under the world w. Notice also that the property *Medium* of the *Subcollection of Spoons* has as value the bag with a single material which is *Wood* as we are interested for the year 1700 and, as it is shown in Figure 4, at this year the *Subcollection of Spoons* were made by *Wood*.

Another temporal snapshot corresponding to a world in which the dimension t has the value 1970 is the conventional RDF graph of Figure 2. In this case the value of the dimension v does not play any role in this snapshot.

Notice that it is often interesting to specialize an MRDF graph only with respect to specific values of some of the dimensions on which the graph depends on. Consider for example that we want to find the state of the graph as it was in time $t = 2003$. In this case it is not given a specific value for the dimension v. It is easy to see intuitively that the graph obtained from such a reduction is not an RDF graph but it is instead an MRDF graph as both facets of the object of the property *Medium*, along with the corresponding context information is retained. This kind of reduction is called *partial reduction* and it is slightly different from the reduction procedure presented above.

6 Discussion and Future Work

The current research presents a metadata model rich enough to adequately express a variety of requirements concerning the manipulation of temporal information in cultural collections. The incorporation of time in a metadata model for cultural collections is important as it facilitates the metadata navigation across time. We demonstrated that we need two time dimensions; the first corresponds to the historical reference of the content of the cultural collection while the second to the collection management through the time. For this purpose we adopted the MRDF formalism, which allows multiple time dimensions. Using this formalism, the value of each element of our application profile may be time dependent and in this way it becomes easy to encode the evolution of the collection over time as well as the temporal information of the collection's content. To the best of our knowledge this is the first work on defining an application profile which allows to fully record the history of its elements. On the other hand, the use of MRDF formalism is essential as it is the only extension of MRDF which allows multiple (time) dimensions. Other temporal extensions of RDF, such as the one proposed in [21] allows only a single time dimension.

The work presented in this paper is related to the work concerning the representation of changes in XML documents [22] and semistructured data [23]. It is also related to the work done in the field of incorporating time in the World Wide Web. An interesting survey on the field can be fount in [24].

Our future work will be directed into:

1. Investigating other aspects of the collection management that present context-dependent behavior. For example such aspects might relate to geographic, purpose of usage or language specific information.

2. Investigating how to query MRDF-graphs and how to store them efficiently.

3. Investigating the problem of the incorporation of time information which is expressed with some degree of fussiness in metadata models for cultural

collections.

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