Linking Objects and their Stories: An API For Exploring Cultural Heritage Using Formal Concept Analysis

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Abstract— **In this paper, we describe a distributed systems and Web Services Architecture that supports a content management and collaborative tagging system for a Web-based cultural heritage site. The site uses Formal Concept Analysis to infer semantic associations between objects and drive the navigation of its collection, and we promote an extension of its capability by rendering such functionality via Web Services. The Web Services architecture supports a system called the Virtual Museum of the Pacific – a content and knowledge acquisition tool that permits the machine synthesis of formal concepts and provides a Rich Internet Application in which to display and navigate them. The Web Services also permit the extensible association of digital objects by inducing new attributes and relationships from museum meta-data, and allows for the ability for users and stakeholders to upload, annotate and attach rich media, YouTube or Vimeo links, and voice narratives to the objects. By rendering these capabilities as an open API, we encourage a connected and open approach to the sharing of cultural heritage and provide platform for further research and development – making our application well suited for mobile devices, Web-based mashups, and data exchange between collection databases.**

I. Introduction

The Virtual Museum of the Pacific is a collaborative project between the Australian Museum and the University of Wollongong that tests the applicability of applying Formal Concept Analysis to cultural collections and assesses their relevance in providing a knowledge discovery experience to its stakeholders. [1] It contains over 400 objects from the Pacific cultural collections of the Australian Museum. It is built based on the philosophy that the meaning behind objects is complex and often inter-related, and that open architecture and API should be implemented so that the richness behind the meta-data of the cultural heritage objects be fully explored. By exposing our functionality via Web Services, developers are free to explore the power of its collaborative tagging, rich media and Formal Concept Analysis based features. We propose that Formal Concept Analysis – described in detail in Section III – can be used to exploit the complex relationships that can exist among objects within cultural collections.

The scope of this paper primarily covers the Web Services and distributed systems architecture for the Virtual Museum of the Pacific. Related work elsewhere covers the Virtual Museum of the Pacific from a design-centric point of view [1] and also discusses the complexities that arise from importing museum meta-data into the system [2]. Related work also discusses the evaluation of the Virtual Museum of the Pacific as en e-Learning tool – a way to connect stakeholders with cultural collections [3]. A similar project, the Art Collection Ecosystem, tests the generality of the software framework and Web Services to other cultural collections [4].

The paper is structured as follows: first, in Section II, we present some of the motivations behind the architecture and design of the Virtual Museum of the Pacific by discussing related work arising from research and practice. In Section III we then give some of the preliminaries of Formal Concept Analysis (FCA), using an example from the Virtual Museum of the Pacific (VMP), so that the paper in self-contained. The navigation architecture that supports the VMP application is the result of more than 10 years of research and practice in applied Formal Concept Analysis [5]–[7] so the paper surveys the literature leading to the present design. We also provide a brief overview of the design features and capabilities of the Virtual Museum of the Pacific in Section IV. We then discuss the bulk of the paper proper in Section V – we examine the detail of the Web Services (WS) architecture supporting the program by providing examples and walkthroughs.

II. Background and Related Work

Digitisation and open access to cultural heritage have long been points of discussion within the museum sector. In her thesis, Jennifer Trant [8] notes that the discussion behind the integration of museum collections using computing technologies, and the linking of these collections via “Virtual Databases” goes back as early as the late 1960s [9]. Even today, she adds that one of the challenges of any student, scholar or enthusiast engaged in cultural heritage is locating the works of art themselves. Art works and artefacts are often distributed across multiple collections with their own, arbitrary set of categories. From the perspective of a user, these online museum collections, while offering a significant improvement over the limited access offered previously, may not be fully satisfactory. Across collection sites, information is often

[1] A prototype version of the system is available at: http://epoc.cs.uow.edu.au/vmp

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presented and structured in ad-hoc ways that mirror the variety of collection databases. In many cases, the online experience of browsing these objects either represents a highly curated selection for a specific purpose or a series of simple object records that are completely de-contextualised: disconnected from the meaning that arises from their cultural context.

The statistics are a telling indication of the miniscule fraction of collections that are actually on physical display – in Australia for instance, there are 180 museums and galleries, yet the last survey in 2008 revealed that only approximately 5% of objects are on display within physical exhibitions.[2] This problem compounds as collections grow in size. Frank Howarth, director of the Australian Museum – the oldest Museum in Australia – discusses the complex relationship that can exist between people who visit collections online and those that walk through the front door of the museum.[3] These relationships can be especially valuable when the technology can enable a connection between remote and diaspora communities and their cultural artefacts, and we represent such a case study for Pacific artefacts within the Virtual Museum of the Pacific. While it is understood that technology alone cannot fulfil a purpose or solve a problem, we believe that the ability to cluster objects using Formal Concept Analysis , to mine their relationships, and to provide the ability to link narrative and rich media and exposing this functionality via an open platform can make significant advances on the ability to develop innovative ways for stakeholders to interact with cultural collections.

Another motivator for exposing cultural collections via APIs is the notion of aggregated cultural heritage portals. Projects such as Europeana[4] and Digital NZ[5] are efforts to aggregate collections from multiple, heterogenous sources. In essence, they provide a federated search and browsing tool to multiple collections and their secondary documents, were data is often fed via API feeds. Digital NZ uses the PowerHouse Museum's API [6] to provide, among other collections, a snapshot of their content. They also provide their own API to provide access to the content that they federate. [7].

Exploration of large, federated collections has been the subject of much academic research. Projects such as the MultimediaN e-Culture demonstrator experiment with third-party Web Services to mine semantic relations across cultural collections [10]. Other research also focuses on the challenging prospects of linguistic processing, term extraction and alignment from these collections [11]. The relevance of this research is strongly linked with the Virtual Museum of the Pacific case study, particularly as we would need to scale our (currently manual approach) of term selection and extraction to larger and more diverse cultural collections.

Initial issues of the terms and vocabulary used in the Virtual Museum of the Pacific where highlighted in a preliminary user acceptance study. The study, conducted with the curatorial, managerial and Web-design staff of the Australian Museum, revealed a generally revealed a positive outlook to the Virtual Museum of the Pacific as an e-Learning tool, particularly for its browsing capabilities and its ability to add or link rich media [3]. Many participants stated that the meta-data within the Virtual Museum of the Pacific is very 'museum-centric' as we derive the terms used for object tagging and annotation from the Australian Museum's own thesaurus. This problem of a 'one-eyed view' of cultural collections is recognised within the literature [8] and projects such as steve.museum [8] and Brooklyn Museum's Tag You're It [9] are initiatives that seek ways for audiences to add meta-data to the collections. We anticipate that our Web Services can create or extend ways for collection access and annotation.

III. Formal Concept Analysis

One of the key features of our application is the ability to cluster similar objects together, or find related sets of other similar objects. Notionally, when one is navigating the Virtual Museum of the Pacific, they are browsing through object clusters rather than individual object records. This is enabled by Formal Concept Analysis and this section will provide a brief introduction to the technology.

Formal Concept Analysis (FCA) [12] is a well-known technique for data analysis that involves the synthesis of a formal concept as a collection of objects that exhibit a common set of attributes. FCA offers a formalization of concepts understood in the philosophical tradition, namely where a concept is considered a unit of thought constituted by its extension and its intension. In FCA, the extension and intension can respectively represent objects (such as certain Pacific artefacts) and attributes (particular qualities that describe those Pacific artefacts). The theory of FCA argues [13] that by directly representing the context in which formalized concepts are defined, it is possible to provide enough references to allow the interpretation of the formalized concepts in human communication and augmentation. In this way the Virtual Museum of the Pacific provides clusters of interrelated objects – each cluster having specific attributes or qualities.

A *formal context* $K := (G, M, I)$ is a triple where G is a set of formal *objects*, M is a set of *attributes* and I is an *incidence* relation between the objects and the attributes. $I \subseteq G \times M$ is a binary relation where $(g, m) \in I$ is read

[2] http://www.abs.gov.au/ausstats/abs@.nsf/mediareleasesbytitle/3B2382C52CCEDD38CA257585007E1E3F?OpenDocument

[3] A transcript of the radio interview with Frank Howarth conducted by ABC Radio National can be found here: http://www.abc.net.au/rn/futuretense/stories/2009/2666242.htm

[4] http://www.europeana.eu/portal/

[5] http://www.digitalnz.org/

[6] http://api.powerhousemuseum.com/login/?next=/

[7] http://www.powerhousemuseum.com/dmsblog/index.php/2008/12/02/digitalnz-api-access-to-new-zealand-collections-launches/

[8] http://www.steve.museum/

[9] http://www.brooklynmuseum.org/opencollection/tag_game/start.php

"object g has attribute m" and written gIm. A formal context can be represented as a cross-table where the rows represent objects (G), the columns attributes (M) and the incidence relation I by a series of crosses as shown in Tab. I.

A formal concept can be derived by taking an object and collecting all attributes describing it, then collecting all objects described by those attributes. For instance, taking the object *e002509*, let B be its attributes, $B = \{\text{body accessories, fan, melanesia, fiji}\}$. Now, let A be the objects that have all attributes in B. $B = \{\text{e002509, e090525}\}$ so the formal concept (A, B) is $\{\{\text{e090525, e002509}\}, \{\text{body accessories, fan, melanesia, fiji}\}\}$.

Concepts can be arranged in a specialization hierarchy. A concept (A, B) is a sub-concept of another concept (C, D) if $A \subseteq C$ (or equivalently $B \supseteq D$). Via this definition, more specific concepts have fewer objects and more attributes, e.g, $(A, B) < (C, D)$ where $(A, B) = \{\text{e002509, e090525}\}$, $\{\text{body accessories, fan, melanesia, fiji}\}\}$ and $(C, D) = \{\{\text{e050525, e002509, e058551-004}\}$, $\{\text{body accessories,melanesia,fiji}\}\}$.

The set of all formal concepts of a formal context, together with the specialization relation, forms an algebraic structure called a concept lattice [12] shown in Fig. 1 and denoted $\underline{B}(K)$, where K is the formal context. The concept lattice provides a mechanism to visualize information contained within a formal context. Evident from the diagram is the specialization hierarchy over the concepts and also the implicational logic between objects and attributes that are implicit in the context, so for example all $\{\text{head ornament}\} \rightarrow \{\text{body accessories, polynesia, samoa}\}$.

Further, let (G, M, W, I) be a many valued context and for each $m \in M$ let $S_m := (G_m, M_m, I_m)$ be a scale for m. The *derived context* of (G, M, W, I) with respect to *plain scaling* with the scales $(S_m | m \in M)$ is then (G, N, J) where:

$$N := \prod_{m \in M} \{m\} \times M_m \quad \text{and}$$

$$(g, (m, n)) \in J :\leftrightarrow \exists_{w \in W} (g, m, w) \in I \text{ and } (w, n) \in I_m.$$

TABLE I.
THE FORMAL CONTEXT $K := (G, M, I)$ CONTAINING INFORMATION ABOUT THE OBJECTS (G) AND THEIR ATTRIBUTES (M) FOR THE SUB-CONTEXT RESULTING FROM APPLYING "BODY ACCESSORY" AND "ORIGIN" SCALES.

K	body accessories	fan	head ornament	ankle ornament	fly whisk	neck ornament	melanesia	polynesia	fiji	papua new guinea	samoa
e002509	×	×					×		×		
e090525	×	×					×		×		
e058551-004	×				×		×		×		
e091567	×					×		×	×		
e091570	×					×	×		×		
e002415	×	×						×			×
e002416	×	×						×			×
e058169	×		×					×			×
e058169	×				×			×			×
e011543	×			×			×			×	

This definition of a many-valued context allows for the creation of contexts that include cells that contain something other than a boolean (×) value and permits the presentation of attributes and their values in Formal Concept Analysis . Conceptual scales [14] are a powerful tool that can be used to store views that partition the data being analysed. For example, Fig. I is actually a sub-context combining two conceptual scales for "body accessory" and "origin", this can be seen by the fact that "body accessory" an attribute common among all the objects in the content and that the mutually exclusive attributes "polynesia" and "melanesia" are present for each object in the context. Within a FCA system multiple views can be stored and combined to effectively query the data, "body accessory" and "origin" (shown in Fig. I) are 2 of 15 predefined conceptual scales used in the VMP which include other scales, "general keywords", "indigenous names", "archaelogy", "body enhancements", "clothing", "container", "hunting fishing weapon", "pastime", "raw material artefacts", "spiritual", "tool", "textile and equipment" and "materials". Other scales (which we call perspectives in the user interface but can also be considered as facets in an information retrieval sense) can be defined by the stakeholders depending on their interests. In our implementation, we allow the ability to add new attributes (or tags to objects) and create custom conceptual scales (or perspectives) via Web Services.

For example, a given community of stakeholders could have a restricted view of the 15 predefined scales according to their access authority. Scales can be pre-defined and customized based on the attributes they contain. The attributes themselves can be introduced into the vocabulary and these then become candidate tags that can be used in the control vocabulary. The use of scales also induces sub-contexts of a formal context that reduce the computational complexity of formal concept analysis.

In the Virtual Museum of the Pacific, attributes are drawn from a control vocabulary, which the museum calls a thesaurus. Where they are drawn from free-text, or form part of a free-text description, they are checked by an anthropologist to ensure that they are normalized with respect to the control. A normalized vocabulary is important for user navigation and computational complexity since the proliferation of similar attribute names would impact negatively on both. [15].

IV. Virtual Museum of the Pacific

The Virtual Museum of the Pacific (VMP) (Fig. 2) tests the relevance of concept-lattice based searching and browsing in the context of organising digitised museum content — specifically in terms of enabling contextually sensitive annotation and access to the collections.

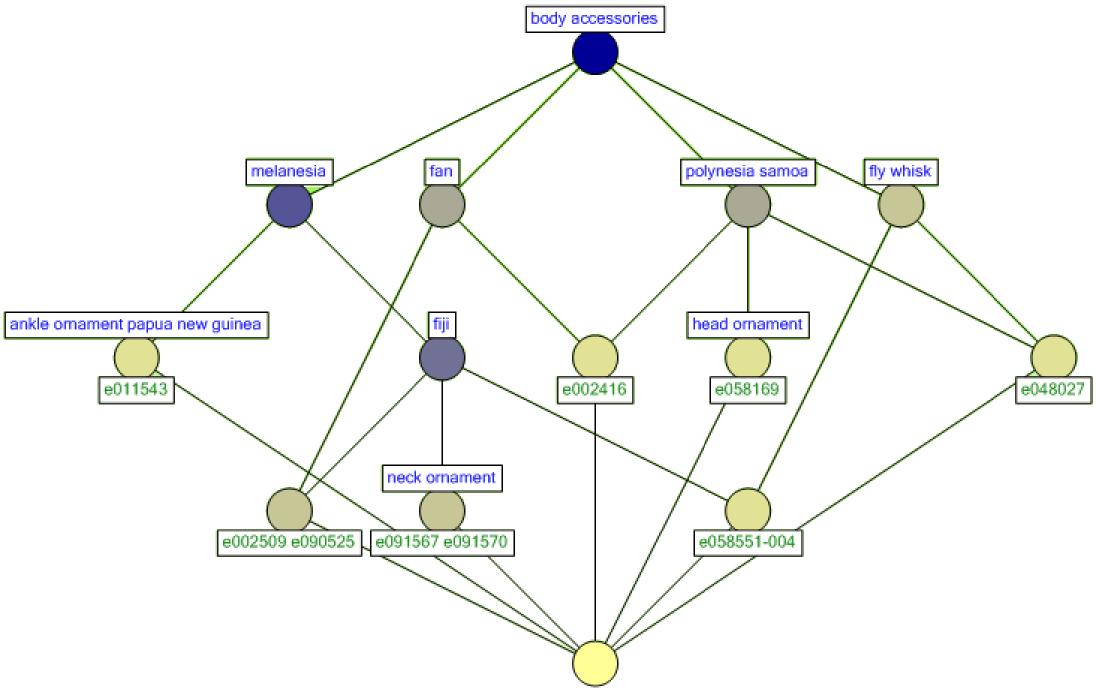
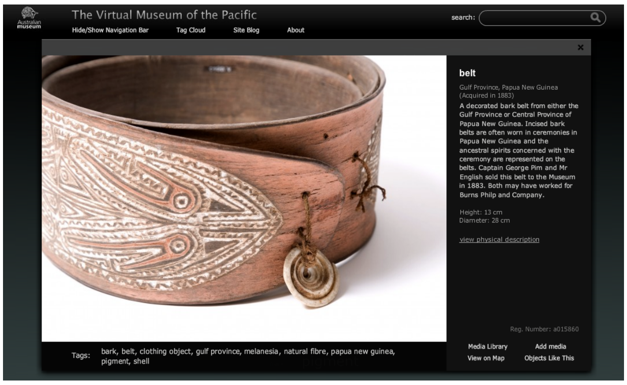


Figure 1. The corresponding line diagram ($\underline{B}(K)$) of the cross-table (context) presented in Table I.

The project investigates the concept-lattice's potential for multi-dimensional browsing. One of the underdeveloped areas of an otherwise mature FCA technology is in terms of its implementation as a Web Services (WS) architecture (shown in Fig. 7), novel in that it is the first WS implementation of FCA but also necessitated by the deployment architecture for a Web-based collaborative tagging system and for system scalability, particularly for its ability to add and link rich media. This section will provide a brief overview of the Virtual Museum of the Pacific by outlining some of its key design features.



belt

Gulf Province, Papua New Guinea
(Acquired in 1883)

A decorated bark belt from either the Gulf Province or Central Province of Papua New Guinea. Incised bark belts are often worn in ceremonies in Papua New Guinea and the ancestral spirits concerned with the ceremony are represented on the belts. Captain George Pim and Mr English sold this belt to the Museum in 1883. Both may have worked for Burns Philp and Company.

Height: 13 cm
Diameter: 28 cm

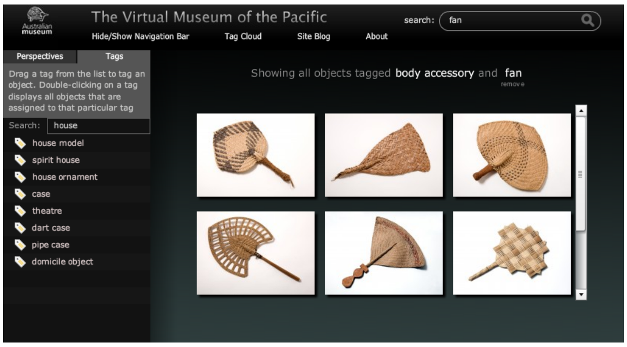
Reg. Number: a015860

Tags: bark, belt, clothing object, gulf province, melanesia, natural fibre, papua new guinea, pigment, shell

Figure 2. A typical screenshot of the Virtual Museum of the Pacific, showing a belt from the Gulf Province of Papua New Guinea

A. Navigation & Conceptual Neighborhoods

The design of the Virtual Museum of the Pacific (VMP) results from considerable prior art in using Formal Concept Analysis to navigate information spaces [5]–[7].Kim and Compton [16] developed a document navigation interface using Formal Concept Analysis and a conceptual neighborhood display. Their program, *KANavigator* uses annotated documents that can be browsed by keyword and displays the direct neighborhood (in particular the lower neighbors) as its interface. *KANavigator* emphasized the use of textual labels as representations of formal concepts (as opposed to a line diagram of the concept lattice shown in Fig 1). Upstream usability studies have shown that an interface based on a conceptual neighborhood has significant merit [17], simplifying the interaction and enabling non-expert users to intuitively interact with a concept lattice.

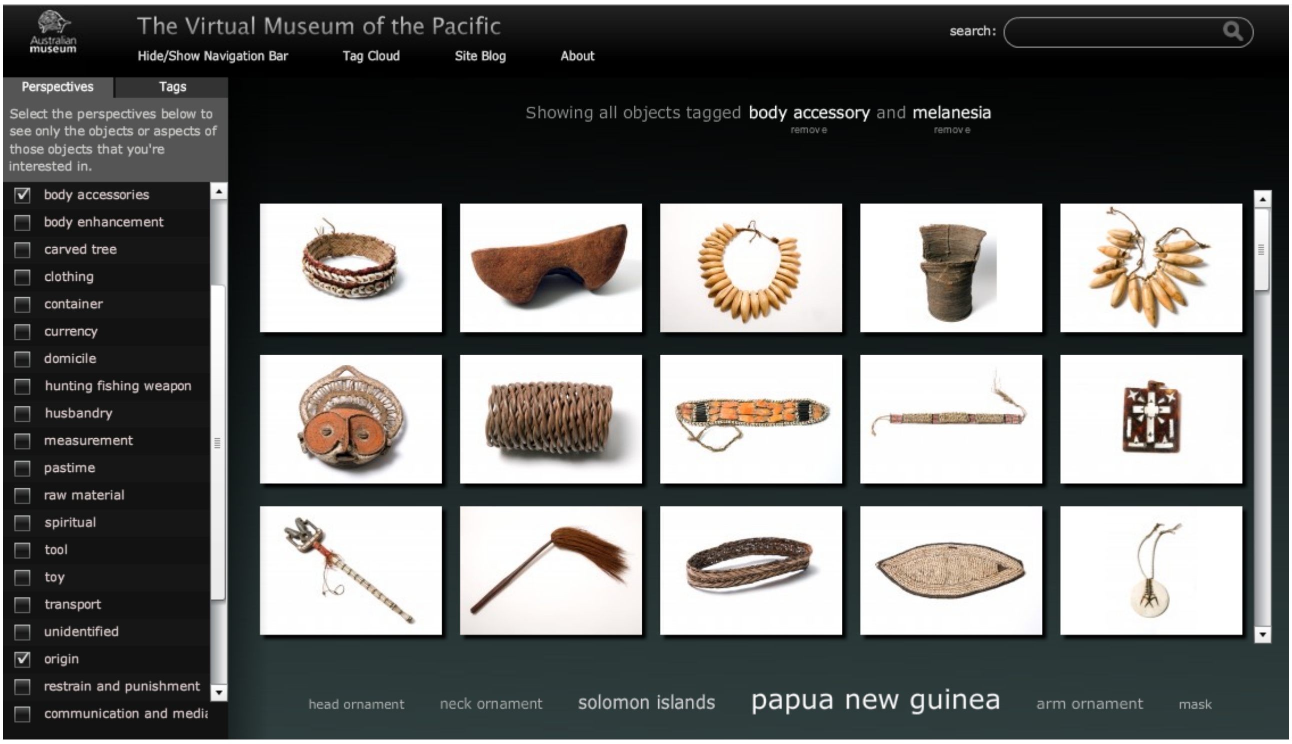


Drag a tag from the list to tag an object. Double-clicking on a tag displays all objects that are assigned to that particular tag

- house model
- spirit house
- house ornament
- case
- theatre
- dart case
- pipe case
- domicile object

Showing all objects tagged body accessory and fan

Figure 3. The tagging interface of the VMP, tags (on the left) are from a large control vocabulary defined by the Australian Museum. Query expansion is done through both the search and tagging process - for instance, a search for the tag 'housing' corresponds to vocabulary items 'house ornament', 'case' and 'domicile object.' The view shown in the figure corresponds to the formal concept labeled "fan" (2nd left-from the top) in Fig. 1



Select the perspectives below to see only the objects or aspects of those objects that you're interested in.

- ☑ body accessories
- ☐ body enhancement
- ☐ carved tree
- ☐ clothing
- ☐ container
- ☐ currency
- ☐ domicile
- ☐ hunting fishing weapon
- ☐ husbandry
- ☐ measurement
- ☐ pastime
- ☐ raw material
- ☐ spiritual
- ☐ tool
- ☐ toy
- ☐ transport
- ☐ unidentified
- ☑ origin
- ☐ restrain and punishment
- ☐ communication and medi

Showing all objects tagged body accessory and melanesia

Figure 4. Screenshot of the Virtual Museum of the Pacific showing the pre-defined perspectives (scales) on the left which can be activated by checkboxes. In this case both "body accessories" and "origin" and selected. These become facets of the current display of the objects.

The Virtual Museum follows from an earlier program called ImageSleuth [7]. Like the Virtual Museum of the Pacific, ImageSleuth allows the user to view one formal concept at a time, and it allows that user to navigate to more specific concepts (lower neighbours) or more generalised concepts (upper neighbours). Objects pertaining to the currently viewing formal concept are represented as thumbnails in the centre of the screen - the group of thumbnails 'grow' and 'shrink' as the user modifies their query. By showing upper and lower neighbors of the current concept and allowing navigation to these concepts, users can refine or generalise their position in the information space. This is aided by the use of pre-defined conceptual scales (called perspectives in the UI) that can be combined to define the attribute set of the lattice that forms the information space (Fig. 4). ImageSleuth underwent an iterative design and usability testing methodology reported in [18]. The results of the usability testing indicated that users were able to find relationships among objects that were previously not apparent.

The Virtual Museum of the Pacific (VMP) interface design employs the conceptual neighbourhood paradigm for browsing and display purposes and supplemented with the ability to tag and annotated objects (images and their metadata) using a control vocabulary and a wiki as shown in Fig. 3. Further, a set of management interfaces and Web Services allows users to create "perspectives" that correspond to conceptual scales described in an earlier section. In addition the user can edit and add new attributes that can then be used to create further perspectives. New objects can also be added to the system allowing the virtual collection content to grow. The program therefore represents an extensible museum content management system with a flexible mechanism for browsing and exploring its set of objects.

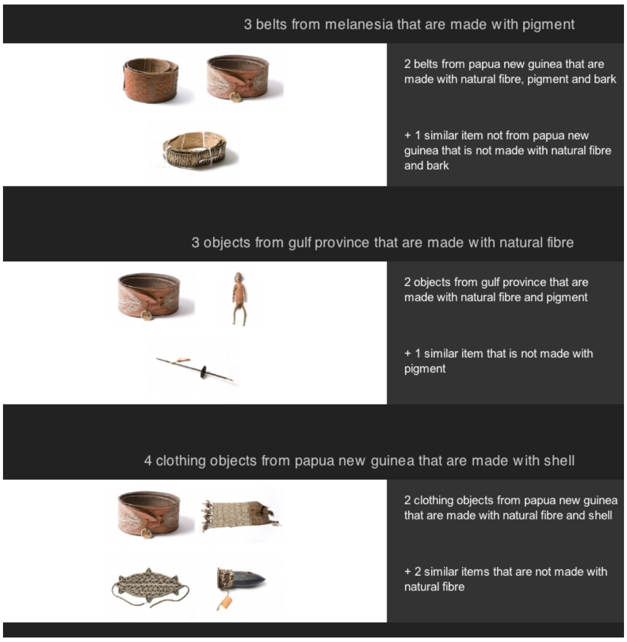
B. Query By Example

In addition to established methods such as keyword search and exclusion/inclusion of attributes that move the user to upper/lower neighbours, the VMP includes a query-by-example function. Metrics on formal concept similarity are discussed and applied to ranking and automated discovery of relevant concepts: from both concepts and semi-concepts and these issues are presented in detail in [19].

In the Virtual Museum of the Pacific, we apply this in our 'Objects Like This' feature where users can view clusters of objects that are semantically and conceptually similar to their current object. For instance, Fig. 5 shows a list of objects (or formal concepts) that have similar attributes to the belt object shown in Fig. 2. These concepts are represented in natural language – describing how the objects within each concept are related. When a user clicks on a result shown in Fig. 5 they are then taken to the conceptual neighbourhood view shown in Fig. 4 where they can further navigate and refine their search.

C. Search and Query Expansion

One of the shortcomings of browsing using Formal Concept Analysis is the relative difficulty of finding a



3 belts from melanesia that are made with pigment

2 belts from papua new guinea that are made with natural fibre, pigment and bark

+ 1 similar item not from papua new guinea that is not made with natural fibre and bark

3 objects from gulf province that are made with natural fibre

2 objects from gulf province that are made with natural fibre and pigment

+ 1 similar item that is not made with pigment

4 clothing objects from papua new guinea that are made with shell

2 clothing objects from papua new guinea that are made with natural fibre and shell

+ 2 similar items that are not made with natural fibre

Figure 5. A list of similar objects, grouped as formal concepts, to the belt in Fig. 2. Here, formal concepts are represented in natural language.

‘starting concept’ to navigate from, particularly if the end user has no to little knowledge of the vocabulary used to describe concepts. To this end, we have implemented a free text search feature that allows users to type in a search string so that relevant formal concepts are displayed, along with search results that are matched according to the free text contained in object descriptions and labels. [10] We implement WordNet-based [20] query expansion and conceptual similarity techniques to expand attribute terms and to improve recall. For instance, a free text search of the term “objects made of bone” reveals the following three formal concepts:

- 15 objects tagged bone
- 6 objects tagged tooth
- 1 object tagged human hair, natural fibre and whale bone

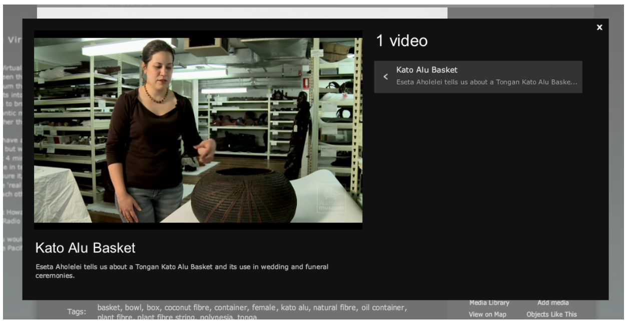
The free text search capabilities attempt to match formal concepts that are relevant to the user’s query. However, there are cases where this isn’t possible. For instance, if the user searches the term “Fijian objects that are made with metal and stone”, the search algorithm would be required to traverse the concept lattice and look for *similar* concepts that may satisfy a user’s information need. This is because there are no actual Fijian objects in the collection that are made of both metal and stone – instead, the algorithm returns the following results:

- 2 objects tagged melanesia, fiji, coconut fibre, stone, wood
- 9 objects tagged metal
- 23 objects tagged melanesia, fiji

In essence, users are limited towards selecting all Fijian objects, all objects made of metal and all Fijian objects made of wood. Like all other features within the Virtual Museum of the Pacific, we operationalise this capability as a Web Service so to facilitate free-text query processing of the Virtual Museum.

D. Rich Media and Annotation

The Virtual Museum of the Pacific also allows the ability for stakeholders to upload video content and audio narratives. All video content is uploaded to Vimeo, which is then referenced within a media player when a user wishes to view rich media associated with an object (Fig. 6). Users can also link Vimeo and YouTube videos by copying and pasting the embed code or URLs. Rich media content can be uploaded and requested via Web Services.



1 video

Kato Alu Basket
Eseta Aholelei tells us about a Tongan Kato Alu Baske...

Kato Alu Basket

Eseta Aholelei tells us about a Tongan Kato Alu Basket and its use in wedding and funeral ceremonies.

Tags: basket, bowl, box, coconut fibre, container, female, kato alu, natural fibre, oil container, plant fibre, plant fibre string, polynesia, tonga

Figure 6. An embedded video, uploaded and stored on Vimeo, that describes a Tongan basket and its use in weddings and ceremonies.

In addition to these rich media capabilities, users can also post commentary and images to object records. This, combined with the ability to link to audio and video annotations, leverages signficant capability in the ability for audiences and creator communities to add their own stories to the Pacific collection.

V. Web Services

The Virtual Museum of the Pacific is driven by a set of Web Services that allow for the navigation and annotation of the Pacific collection and its rich media. It encompasses the entire set of management interfaces that make the objects, their tags (or attributes) and perspectives extensible.

Fig. 7 describes the Web Services architecture of the Virtual Museum of the Pacific. The API feeds off a relational database, although Web Service methods that require computation of concept lattices are processed via a lattice neighbourhood generation engine written in C++. Objects can either be directly referenced from the database or via URIs to external Web Services. Rich media is uploaded and linked to Vimeo, and all video content is referenced and hosted externally.

[10] This feature is available in the Virtual Museum of the Pacific although you can access a HTML-based lightweight version of this at: http://epoc.cs.uow.edu.au/vmpsearch/

In addition to providing XML and JSON response formats, a WSDL interface [11] [12] is also available should developers request client-side generation of proxy classes.

Tables II and III – located at the end of this paper – list all of the Web Service methods available. Examples in this paper will examine a subset of the Web Services in Table III.

It is common practice to provide access Web Service methods via a URL with parameters, and have the results returned as XML. For the examples in this paper, the format of the request URL is as follows:

```
http://epoc2.cs.uow.edu.au/vmpws/{frmt}/?
   apikey={your api key}
   &method={method name}
   &param=value
   &param=value
   ...
```

In the example URL `{frmt}` represents the desired response format – valid values being either `xml-http` or `json`. The application (or user's) API Key goes in place of `{your api key}` . `{method name}` represents the name of the method you would want to call, and a series of `{param=value}` pairs represents parameter names and their values respectively. Some methods require an array rather than a single value for a given parameter. In this case, multiple values are delimited by the `|` symbol, so for instance, a parameter that contains an array of three values would be represented as `param=|value1|value2|value3` . All read-only methods (Table III) rely on a constructed URL, using HTTP GET. The following API key will be used to query the read-only methods described in this paper.

```
REA-3DFGHK-5GHBNK-23DNVS-1LDVGH
```

This section of the paper will continue with common use cases for retrieving a single object record, navigating the collection, finding similar objects, and loading rich media.

A. *Use Case 1 : Retrieving a Single Object Record*

A common use case for a collection API is to retrieve information about a specific object. To this end we call the *getObject* method using the following URL:

```
http://epoc2.cs.uow.edu.au/vmpws/xml-http/?
   apikey=REA-3DFGHK-5GHBNK-23DNVS-1LDVGH
   &method=getObject
   &regnumber=e090764
```

This query returns the associated meta-data for object of registration number *e090764*. The registration number is the unique identifier used to identify all objects within the Australian Museum's CMS. The `<tags>` element describes the attributes associated with this particular object record.

```
<rsp status="ok">
    <regNumber>e090764</regNumber>
    <category>
     hunting fishing weapon object
    </category>
    <itemName>fishing implement</itemName>
    <acqRegDate>1992-02-11</acqRegDate>
    <label>
     A small fish trap and float
     (an kulkula, kip) from the Tanga
     Islands in the New Ireland ...
    </label>
    <description>
     Fish trap and float. Trap consists
     of a conical frame, made from small
     sticks with thorns on them, ...
    </description>
    <indigenousNames>
        <item>an kulkula</item>
        <item>kip</item>
    </indigenousNames>
    <materials>
        <item>thorn</item>
        <item>fruit</item>
        ...
    </materials>
    <keywords>
        <item>fishing</item>
        <item>food gathering</item>
    </keywords>
    <location>
        <areaGroup>melanesia</areaGroup>
        <country>papua new guinea</country>
        <state>new ireland province</state>
        <region>tanga group</region>
    </location>
    <dimensions>
        ...
    </dimensions>
    <tags>
        <item>fishing implement</item>
        <item>fruit</item>
        <item>leaf</item>
        ...
    </tags>
</rsp>
```

[11] A WSDL file of a prototype version of the Web Services are available at: http://epoc.cs.uow.edu.au/vmpws/soap/?wsdl. Documentation and command-level access of the WSDL interface is available at: http://epoc.cs.uow.edu.au/vmpws/soap/? Note that not all methods are accessible via WSDL / SOAP and still require the use of HTTP GET / XML, for example *addUserCommentImage* requires a file upload and is not available within the WSDL file.

[12] You are required to use an API Key to access any of the methods: the following key – REA-3DFGHK-5GHBNK-23DNVS-1LDVGH-7DFGHKL – can be used to access read-only methods (methods beginning with 'get') and will be used throughout examples in this paper

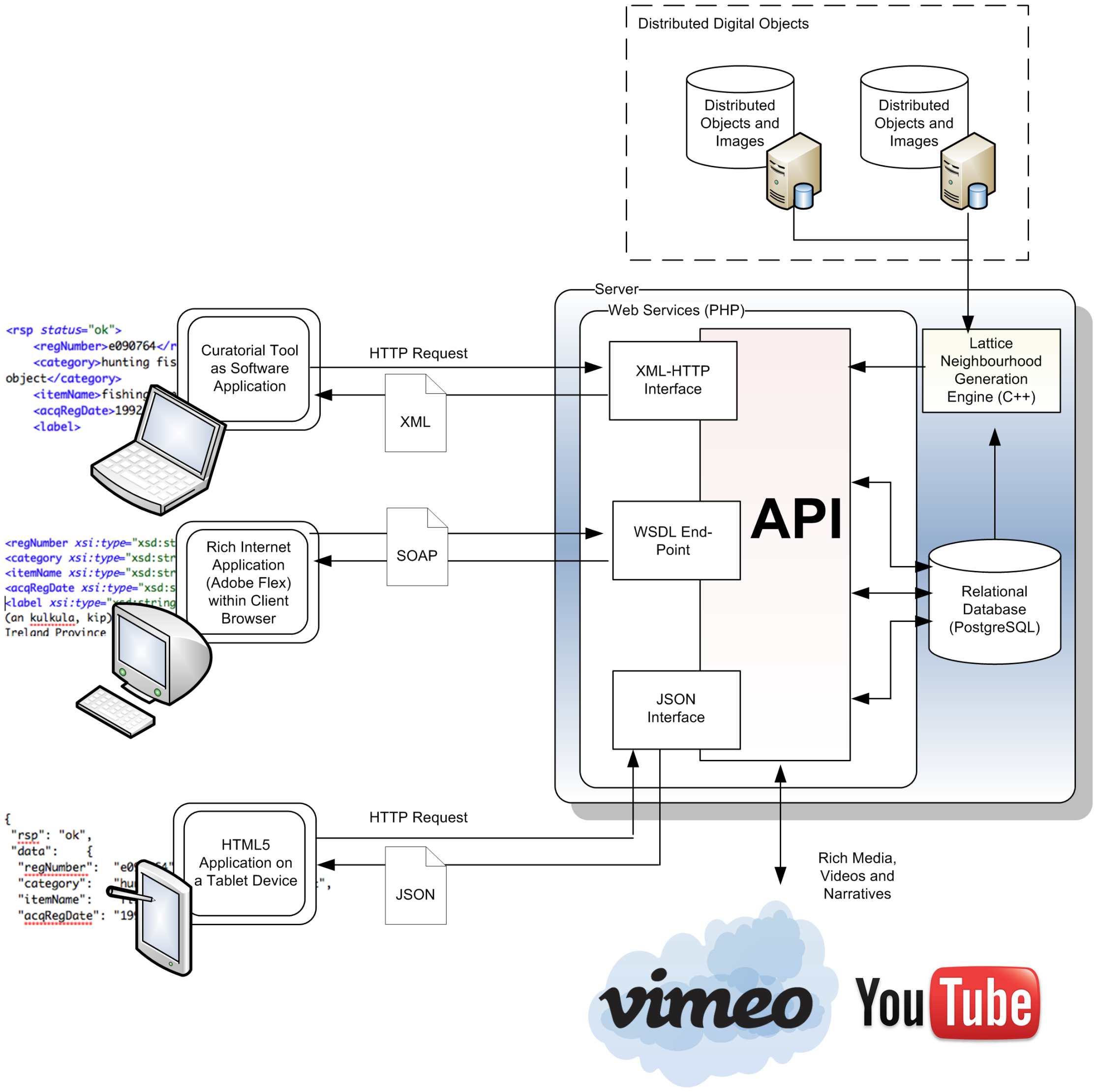

Distributed Digital Objects
Distributed Objects and Images
Distributed Objects and Images
Server
Web Services (PHP)
Lattice Neighbourhood Generation Engine (C++)
XML-HTTP Interface
WSDL End-Point
JSON Interface
API
Relational Database (PostgreSQL)
Curatorial Tool as Software Application
HTTP Request
XML
Rich Internet Application (Adobe Flex) within Client Browser
SOAP
HTML5 Application on a Tablet Device
HTTP Request
JSON
Rich Media, Videos and Narratives
vimeo
YouTube

Figure 7. The architecture for the Virtual Museum of the Pacific, see http://epoc.cs.uow.edu.au/vmpws/soap/? for command-level access to the VMP Web Service WSDL interface

B. Use Case 2 : Searching and Navigating the Collection

The Web Services provide an API that allows you to search and navigate a collection. As with many other online collection APIs, these Web Services provide a search interface as a starting point. For instance, once could simply call the *getObjectsFromPlainTextQuery* method to perform a text search on the object descriptions. This method returns references to single object records along with their free-text matches. Our example calls this method with the search string “fijian house items” using the following URL:

```
http://epoc2.cs.uow.edu.au/vmpws/xml-http/?
   apikey=REA-3DFGHK-5GHBNK-23DNVS-1LDVGH
   &method=getObjectsFromPlainTextQuery
   &query=fijian+house+items
```

```
<rsp status="ok">
    <item>
        <regNumber>pun1142</regNumber>
        <headline>
           <b>house</b> model square base;
           steeply sloping, four-sided roof
           capped with wooden ridgepole ...
        </headline>
    </item>
    <item>
        <regNumber>e084307</regNumber>
        <headline>
           <b>Fijian</b> Drua or Ndrua shows
           the typical double hull of equal
           size. These seafaring canoes ...
        </headline>
    </item>
</rsp>
```

However, our interface primarily relies on navigation using formal concepts, rather than single object records, so therefore we have developed the *getConceptsFromPlainTextQuery* method to match and approximate formal concepts to a search string. The following lists the request URL and XML result for the *getConceptsFromPlainTextQuery* method.

```
http://epoc2.cs.uow.edu.au/vmpws/xml-http/?
   apikey=REA-3DFGHK-5GHBNK-23DNVS-1LDVGH
   &method=getConceptsFromPlainTextQuery
   &query=fijian+house+items
```

```
<rsp status="ok">
    <item>
        <match_ranking>1</match_ranking>
        <query_terms>
            <item>fiji</item>
            <item>house model</item>
        </query_terms>
        <matching_formalConceptIntent>
            <item>architecture object</item>
            <item>house model</item>
            <item>melanesia</item>
            <item>fiji</item>
        </matching_formalConceptIntent>
        <inferred_terms>
            <item>architecture object</item>
            <item>melanesia</item>
        </inferred_terms>
        <extent_size>1</extent_size>
        <objects>
            <item>pun1142</item>
        </objects>
    </item>
    <item>
        <match_ranking>0.8</match_ranking>
        <query_terms>
            <item>fiji</item>
            <item>domicile object</item>
        </query_terms>
        <matching_formalConceptIntent>
            <item>domicile object</item>
            <item>melanesia</item>
            <item>fiji</item>
        </matching_formalConceptIntent>
        <inferred_terms>
            <item>melanesia</item>
        </inferred_terms>
        <extent_size>3</extent_size>
        <objects>
            <item>e002535</item>
            <item>e028221</item>
            <item>e046814</item>
        </objects>
    </item>
</rsp>
```

This method returns two formal concepts that match or approximate the query "fijian house items". The `<matching_formalConceptIntent>` tag denotes the attributes of each matching formal concept – these are attributes sets { architecture object, house model, melanesia, fiji } and { domicile object, melanesia, fiji }.

We can use these attributes to subsequently retrieve conceptual neighbourhood information. For instance, we can retrieve all objects that are tagged { domicile object, melanesia, fiji }, along with their links to more generalised and specialised concepts. One could naturally do this using the *getConcept* method although that method also requires a set of perspectives (conceptual scales) to perform the query. Therefore, we need to know all perspectives that belong to attributes { domicile object, melanesia, fiji }. In order to streamline this workflow for developers, we have created the *getPerspectivesForTags* method that fulfils this purpose.

```
http://epoc2.cs.uow.edu.au/vmpws/xml-http/?
   apikey=REA-3DFGHK-5GHBNK-23DNVS-1LDVGH
   &method=getPerspectivesForTags
   &tags=|domicile+object|melanesia|fiji
```

```
<rsp status="ok">
    <item>
        <name>domicile object</name>
        <perspectives>
            <item>domicile</item>
            <item>general keywords</item>
        </perspectives>
    </item>
    <item>
        <name>melanesia</name>
        <perspectives>
            <item>origin</item>
        </perspectives>
    </item>
    <item>
        <name>fiji</name>
        <perspectives>
            <item>origin</item>
        </perspectives>
    </item>
</rsp>
```

From this point we can retrieve a formal concept with attributes { domicile object, melanesia, fiji } using the *domicile*, *general keywords* and *origin* perspectives.

```
http://epoc2.cs.uow.edu.au/vmpws/xml-http/?
   apikey=REA-3DFGHK-5GHBNK-23DNVS-1LDVGH
   &method=getConcept
   &tags=|domicile+object|melanesia|fiji
   &perspectives=|domicile|general+keywords
              |origin
   &computefullconcept=true
```

The results (shown next page) retrieve a formal concept (the corresponding objects and tags) along with `<upperNeighbourNavigations>` and `<lowerNeighbourNavigations>` links. These links, each with a `remove` or `include` method, provide a way to perform subsequent queries on the *getConcept* method so that it can provide users with a means of navigating to more general (upper neighbour) or more specific (lower neighbour) formal concepts. For instance, the first item in the `<upperNeighbourNavigations>` node has a `remove` method on tag `domicile object` with an extent size of `23` (indiciating that if we remove *domicile object* from our current search view, the result will be 23 objects tagged { melanesia, fiji }. To navigate to the upper neighbour, you would then subsequently re-query the *getConcept* with the same query as above but with the reducded set of tags { melanesia, fiji }.

```
<rsp status="ok">
    <formalConcept>
        <objects>
            <item>e046814</item>
            <item>e028221</item>
            <item>e002535</item>
        </objects>
        <tags>
            <item>domicile object</item>
            <item>melanesia</item>
            <item>fiji</item>
        </tags>
    </formalConcept>
    <inferred_tags/>
    <upperNeighbourNavigations>
        <item>
            <method>remove</method>
            <extent_size>23</extent_size>
            <tags>
                <item>domicile object</item>
            </tags>
        </item>
        <item>
            <method>remove</method>
            <extent_size>31</extent_size>
            <tags>
                <item>fiji</item>
            </tags>
        </item>
    </upperNeighbourNavigations>
    <lowerNeighbourNavigations>
        <item>
            <method>include</method>
            <extent_size>1</extent_size>
            <tags>
                <item>headrest</item>
            </tags>
        </item>
        <item>
            <method>include</method>
            <extent_size>1</extent_size>
            <tags>
                <item>fork</item>
            </tags>
        </item>
        <item>
            <method>include</method>
            <extent_size>1</extent_size>
            <tags>
                <item>food hanger</item>
            </tags>
        </item>
    </lowerNeighbourNavigations>
</rsp>
```

The *getConcept* method also handles perspective changes. This is done by altering the `perspectives` parameter in the query string. For instance, if you would wish to activate the *materials* perspective in the current search so that your users can refine their view via an object's materials, you would simply modify the perspectives parameter so that it appears as `perspectives=|domicile|general+keywords |origin|materials`. Once the method is called, the conceptual neighbourhood is re-computed with the *materials* perspective activated.

You can also represent formal concepts in a more natural and intuitive way by using the *getConceptNaturalLanguage* method. To represent the above formal concept as a natural language expression, one would call the following method:

```
http://epoc2.cs.uow.edu.au/vmpws/xml-http/?
   apikey=REA-3DFGHK-5GHBNK-23DNVS-1LDVGH
   &method=getConceptNaturalLanguage
   &tags=|domicile+object|melanesia|fiji
     |natural+fibre
   &objects=|e046814|e028221|e002535
```

```
<rsp status="ok">
    <formalConcept>
        <tags>
            <item>domicile object</item>
            <item>melanesia</item>
            <item>fiji</item>
            <item>natural fibre</item>
        </tags>
        <objects>
            <item>e046814</item>
            <item>e028221</item>
            <item>e002535</item>
        </objects>
    </formalConcept>
    <naturalLanguageExpression>
       3 domicile objects from fiji that
       are made with natural fibre
    </naturalLanguageExpression>
</rsp>
```

This method infers an expressive string, based on the attributes provided, and provides user-friendly expression of a current point within the information space of the collection.

C. Use Case 3: Finding Similar Objects

The Web Services provide powerful methods to perform content-based retrieval and query by example operations. The *getSimilar* method can be used to find formal concepts based on conceptual distance and similarity. An example *getSimilar* URL request follows:

```
http://epoc2.cs.uow.edu.au/vmpws/xml-http/?
   apikey=REA-3DFGHK-5GHBNK-23DNVS-1LDVGH
   &method=getSimilar
   &tags=|domicile+object|fiji|food+hanger
       |natural+fibre|wood
   &perspectives=|domicile|origin|materials
   &searchwidth=100
```

```
<rsp status="ok">
    <statistics>
        <computed>22</computed>
        <border>13</border>
        <internal>9</internal>
        <searchWidth>100</searchWidth>
    </statistics>
    <searchResults>
        <item>
            <score>95.72</score>
            <distance>0.99</distance>
            <similarity>0.91</similarity>
            <formalConcept>
                <tags>
                    <item>domicile</item>
                    <item>food hanger</item>
                    <item>wood</item>
                    <item>melanesia</item>
                    <item>fiji</item>
                    <item>fibre</item>
                </tags>
                <objects>
                    <item>e028221</item>
                </objects>
            </formalConcept>
        </item>
        <item>
            <score>70.4</score>
            <distance>0.99</distance>
            <similarity>0.41</similarity>
            <formalConcept>
                <tags>
                    <item>wood</item>
                    <item>melanesia</item>
                    <item>fiji</item>
                    <item>fibre</item>
                </tags>
                <objects>
                    <item>b007263</item>
                    <item>e028221</item>
                    <item>e084307</item>
                </objects>
            </formalConcept>
        </item>
                <item>
            <score>70.4</score>
            <distance>0.991382</distance>
            <similarity>0.416667</similarity>
            <formalConcept>
                <tags>
                    <item>domicile</item>
                    <item>wood</item>
                    <item>melanesia</item>
                    <item>fiji</item>
                </tags>
                <objects>
                    <item>e002535</item>
                    <item>e028221</item>
                    <item>e046814</item>
                </objects>
            </formalConcept>
        </item>
    </searchResults>
</rsp>
```

The *getSimilar* method returns an list of formal concepts, order-ranked according to their distance and similarity metrics [21]. This can be used to provide relevant matches to a formal concept, or even as a query by example feature for a given object as described in Section IV-B. This is done by using the *getObject* method to retrieve the tags (attributes) for the object, then the *getPerspectivesForTags* methods to extract their perspectives so that the *getSimilar* method can perform the necessary computations. The results can be presented in a user-friendly readable form using the *getConceptNaturalLanguage* method to present the results. Following this approach, the above XML query result can be represented as follows:

7 objects that are similar to this food hanger from Fiji that is made with wood and natural fibre:

- 1 food hanger from Fiji that is made with fibre and wood
- 3 objects from Fiji that are made with fibre and wood
- 3 domicile objects from Fiji that are made with wood

D. Use Case 4 : Accessing Rich Media

The Web Services also provide access to rich media, video and audio clips associated with an object. The *getMediaItemsForObject* method is used to display a list of rich media items for a given object record.

```
http://epoc2.cs.uow.edu.au/vmpws/xml-http/?
   apikey=REA-3DFGHK-5GHBNK-23DNVS-1LDVGH
   &method=getMediaItemsForObject
   &regnumber=h000359
```

```
<rsp status="ok">
    <mediaItem>
        <uri>
           6cd7515fb71e50480d0d995b03df114f
        </uri>
        <metadata>
            <title>
              Amanda Lawson narrates the
              production and motivation
              behind the Virtual Museum ...
            </title>
            <description>
               VMP Media Social Media
            </description>
        </metadata>
   </mediaItem>
    <mediaItem>
        <uri>
           http://vimeo.com/moogaloop.swf/
           clip_id/6500807
        </uri>
        <metadata>
            ...
        </metadata>
   </mediaItem>
</rsp>
```

From that point you can query the *getMediaItem* method to retrieve a media object using the object's registration number and media URI reference. Media URIs can refer to any type of rich media and the response of the *getMediaItem* method depends on whether the media item refers to an audio or video file. The following URL request returns the HTML embed code for a Vimeo file for a given media URI and object registration number reference.

```
http://epoc2.cs.uow.edu.au/vmpws/xml-http/?
   apikey=REA-3DFGHK-5GHBNK-23DNVS-1LDVGH
   &method=getMediaItem
   &regnumber=e012823
   &mediauri=http%3A%2F%2Fwww.vimeo.com%2F
                 moogaloop.swf%3Fclip_id
                 %3D7658586
```

```
<rsp status="ok">
    <video>
        <embed_code>
           <object width="560" height="340">
              <embed
                 src="http://www.vimeo.com/
                 moogaloop.swf?clip_id=7658586"
                 type="application/
                    x-shockwave-flash"
                 allowscriptaccess="always"
                 allowfullscreen="false"
                 width="560" height="340">
              </embed>
           </object>
        </embed_code>
    </video>
</rsp>
```

When the above code in the <embed_code> tag is rendered within a Web browser, the video that is linked to the object should start playing. Using this approach, the system can support the ability to link any type of embed code (either Flash or HTML5 IFrames) irrespective of source or format.

VI. Conclusion

This paper describes the Web Services and API that supports the Virtual Museum of the Pacific, a cultural heritage site and experimental platform that contains over 400 objects from the Australian Museum's Pacific collections. Of particular importance was the way that Formal Concept Analysis can be used to support clustered document browsing, search and navigation, and how the system can be extensible and customisable by expressing such a capability via an API. The paper also provided a general overview of the architecture of the Virtual Museum of the Pacific and described some of its rich media annotation and linking features.

Using Web Services, the system can be entirely extensible and independent of a particular platform. Existing content management systems used within the cultural heritage sector can leverage these Web Services to import and export object records and their meta-data. The system permits both the machine synthesis of formal concepts using Formal Concept Analysis and a set of Web Services that allows the extensible association of digital objects via describing new attributes and relationships in between them. Maximum exposure of object meta-data and system functionality can be used to support mash-ups and creative uses of the Pacific collection and its API.

Acknowledgment

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References

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TABLE II.
LIST OF WEB SERVICE METHODS - MANAGEMENT INTERFACES (LISTED ALPHABETICALLY)

addObjectComment	Adds a single text comment to an object.
addSiteComment	Adds a single text comment to the site blog.
addTagsToObject	Adds a set of tags (attributes) to an object.
addTagsToPerspective	Adds a set of tags (attributes) to a perspective (a conceptual scale). This allows for the creation of customised, user-defined perspectives.
addUserCommentImage	Attaches an image to a user comment. This allows users to post picture comments.
deleteObject	Deletes an object
deletePerspective	Deletes a perspective, or a custom-defined conceptual scale. Pre-defined conceptual scales cannot be deleted.
deleteTag	Removes an tag (attribute) and un-tags all objects associated with that tag
deleteTagsFromObject	Removes a set of tags (attributes) from an object
deleteTagsFromPerspective	Removes a set of tags (attributes) from a perspective (conceptual scale). This allows for the modification of customised, user-defined perspectives.
renameObject	Changes an object's ID (or registration number)
renamePerspective	Changes the name of a perspective (conceptual scale)
renameTag	Changes the name of a tag (or attribute). Consequently, all tag references as they are assigned to objects are renamed and updated
saveObject	Creates a new object record, or modifies an existing one
savePerspective	Creates a new perspective (conceptual scale), or modifies an existing one. This allows for the creation of customised perspectives
saveTag	Creates a new tag (attribute) or modifies an existing one. Here you can define relationships between attributes by specifying child or parent relations (eg. tag 'wood' is a sub-type of 'plant material' which is a sub-type of 'material')
saveUser	Creates a new user account, or modifies an existing one

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TABLE III.
LIST OF WEB SERVICE METHODS - READ ONLY (LISTED ALPHABETICALLY)

Method Name	*Description*
getAllPerspectives	Gets the names and IDs of the entire set of perspectives available within the Virtual Museum of the Pacific
getConcept	Gets a formal concept based on a given set of tags (attributes) and perspectives. Returns the objects that are associated with those tags, along with a list of its upper neighbour and lower neighbour navigations.
getConceptNaturalLanguage	Gets a plain text, natural language expression for a formal concept, defined by a given set of tags (attributes) and perspectives.
getConceptsFromPlainTextQuery	Gets a list of formal concepts that match, or approximate, a plain text search query
getExtractedTermsForObject	Gets a list of extracted and normalised tags for an object based on its description, labels, comments and annotations. This method uses Yahoo's Term Extraction Web Service to do this, and the terms are matched and normalised using WordNet.
getMediaItem	Gets a single media item (video or audio clip) for a given object identifier and media URI. If the media item is a video object, the HTML embed code for the video is returned. It is an audio clip, the URL for the streaming MP3 clip is returned.
getMediaItemsForObject	Gets a list of media URIs for a single object
getObject	Gets a single object record, returning its description, origin and tags (attributes)
getObjectComments	Gets a list of comments for a single object record
getObjectsFromPlainTextQuery	Gets a list of objects that match, or approximate, a plain text search query
getPerspectives	Gets information and a set of tags for a single perspective (conceptual scale)
getPerspectivesForTags	Retrieves the set of perspectives that belong to a set of tags. Often used in optimising queries to *getConcept* or *getSimilar* by determining the minimum set of conceptual scales required for a given query
getSimilar	Retrieves a list of similar concepts, based on a set of tags (attributes) and perspectives. The similar concepts are order-ranked from most similar to least similar. This method is used within the *getConceptsFromPlainTextQuery* method to approximate search results, and is used extensively within the 'Objects Like This' feature described in Section IV-B.
getSiteComments	Retrieves the text comments that are posted on the site blog
getTag	Gets information about a single tag (attribute), including its description, including its direct parent and child tags.
getTagAncestors	Gets a set of ancestor attributes for a given tag
getTagCloudData	Retrieves set of popular tags, each with their own weighting depending on their prevalence within the collection. This method is used to generate visualisations such as tag clouds. Can also be optionally filtered to generate tag cloud data for a given set ofperspective.
getTagDescendants	Gets a set of descendant attributes for a given tag
getTagsFromSearchString	Gets a set of tags (attributes) that correspond to a plain text query.
getTagTree	Retrieves a hierarchical representation of tags. This method can be used to generate visualisations. Can also be optionally filtered to generate a tag hierarchy for a given set of perspectives.