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Designing the Digital Ecosystem of the Virtual Museum of the Pacific

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Abstract—The Virtual Museum of the Pacific is a digital ecosystem implemented as Web 2.0 application that experiments with information and knowledge acquisition for a digital collection of museum artifacts from the Australian Museum. The Virtual Museum of the Pacific allows several search methods: attribute search based on a control vocabulary, query refinement and query-by-example but importantly it facilitates a number of social media interfaces that enable content to be added and tagged, the control vocabulary to be extended, user perspectives to be defined and narratives added via wiki. We characterize the design of the Virtual Museum of the Pacific as: a semantic Web application with a Web services back-end, and as a digital ecosystem by identifying its purpose, function and stakeholders. In doing so, the paper illustrates the issues encountered in its design and deployment, the technical platform, the historical context of the growth of the collection and the challenges to the organization and management of a digital ecosystem metadata model.

I. INTRODUCTION

This paper describes a digital ecosystem based on the representation of an information space derived from concept lattices [25] for tagging, loading and annotating digital objects from a museum collection. The program, a Web 2.0 or Rich Internet Application, is called the Virtual Museum of the Pacific (VMP). It provides an extensible environment for the creation of attribute lists and user-defined perspectives that can be used to flexibly navigate a collection of digital objects based on any user-defined semantic theme. The program also contains a wiki component to encourage its user communities to add narratives to the collection. By facilitating their interaction among stakeholders, and with the collection, the VMP provides a digital ecosystem for the museum's stakeholders.

The paper is structured as follows. First, we present the context in which our system has been developed, namely as the platform for the creation of a Virtual Museum of the Pacific (VMP). Next, we turn to the design of the program surveying the literature leading to the current system: the VMP is the culmination of more than 10 years of research and practice in the use of concept lattices for information browsing [5], [6], [13], [10]. We also examine the feature set of the VMP to provide a snapshot of the current functionality of the system. We explain and present its interfaces and its functionality with reference to an audience with an interest in knowledge modeling and semantic Web applications but also describe

the complexity of the metadata management and standards that necessitate bespoke solutions when implementing a digital ecosystem in virtual museums.

A. Virtual Museum of the Pacific: Context

The Virtual Museum of the Pacific (VMP) is a multi-disciplinary project to create a Web-based knowledge management system for ethnographic objects from the Australian Museum's (AustMus) Pacific Collection. This project tests a new means of facilitating access for indigenous communities [4], [7], museum-reliant researchers and curators – to museum-based digital collections whose artifacts are physically distributed and often not available for public display. The VMP allows more items from a catalog to be publicly displayed than would be possible within the constraints of an actual physical museum displays.

The project has three dimensions: first technically, the project leverages metadata used in curatorial management to produce a rich user experience by representing collection resources as a structured associative network; secondly, at a museological level the project studies an effective means of presenting and interacting with this network for traditional owners, the general public, researchers and curators. Thirdly, the VMP framework is intended as a flexible multimedia platform for creating/composing custom exhibitions.

The research tests the relevance of searching, browsing and tagging in the context of organising digitized museum content — specifically in terms of enabling contextually sensitive annotation and access to the AustMus Pacific collections. The project tests the potential for multi-dimensional tagging and browsing of virtual museum collection resources, in doing so encountering management, social and cultural issues that render the system, the ecosystem design and solution, as a complex engineering and management problem.

B. Navigation and Conceptual Neighborhoods

Kim and Compton [17] developed a document navigation interface using Formal Concept Analysis (FCA)[25] and a conceptual neighborhood display. Their program, *KANavigator* uses annotated documents that can be browsed by keyword. The program displays the direct neighborhood (in

Fig. 1. ImageSleuth: the interface presents only the extent of the current concept as thumbnails and generalizations/specializations by removal/addition of attributes (tags) to reach the upper and lower neighbors (shown to the top/bottom of the thumbnails). Pre-defined scales (called perspectives) are displayed on the left. The thumbnail images shown in the screenshot are from the SIMS2.

particular the lower neighbors) as its interface. At the time, this emphasis on the use of textual labels as representations of single formal concepts (as opposed to a line diagram of the concept lattice) broke with many of the discipline's traditions. However, subsequent usability studies have shown that an interface based on a conceptual neighborhood has significant usability merit [15], simplifying the interaction and enabling non-expert users to intuitively interact with a concept lattice as a representation of an information space.

ImageSleuth 2.0 [13] (shown in Fig. 1), used a similar interface design to allow exploration of image collections. By showing upper and lower neighbors of the current concept and allowing navigation to these concepts, users can refine or generalize their position in the information space. This is aided by pre-defined conceptual scales [25] (called “perspectives”) that are used to define the attribute set of the lattice. This restricts the information space to improve clarity (see Fig. 1 (left)). ImageSleuth underwent an iterative design and usability testing methodology reported in [11].

The VMP interface design follows from ImageSleuth 2.0 and employs the same conceptual neighbourhood paradigm for browsing and display purposes. The VMP is however supplemented with the ability to tag and annotate objects (images and their metadata) using an extensible control vocabulary and a wiki. A set of management interfaces allows users to create new perspectives (concept scales [25]). The user can edit and add new attributes (tags) to the control vocabulary that can be used to create/edit the perspectives.

New objects can 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 adding, exploring and tagging the set of objects in the collection [14].

The digital ecosystem of the Virtual Museum of the Pacific at its simplest level revolves around digital representations of real-world museum artifacts in the virtual collection as individuals. These individuals are encircled by attribute clouds that relate to different feature sets: material, geographic, anthropological, scholarly descriptions, impromptu or informal narratives etc. This architecture is illustrated in Fig. 11.

II. THE ECOSYSTEM OF THE VIRTUAL MUSEUM

The business ecosystem of the Australian Museum (AustMus) is sympathetic to a digital ecosystem treatment because the Museum’s goal is to “to inspire the exploration of nature and cultures”. Further, its context is “to be able to access freely a wide array of knowledge while needing to respect the intellectual property rights of its owners” [1]. Further, many of the AustMus’ objects are too fragile and valuable to handle (and in some cases even display) so a digital rendering of them improves accessibility.

A digital ecosystem is also about the development of new business ecosystems facilitated by ICT. As an example, the British Museum (BM) have a Web-based browsing system [8] that allows visitors to identify objects of interest that they can then personally sponsor research for. This enables a business model in which the user's of the BM can vote (with their money) for the specific objects that are popular, of interest and for which they would like to encourage more research.

To connect the business and digital ecosystems in the VMP we begin with the museum’s collection register. This tangible record of the AustMus’ collection forms the source of important metadata about an object, e.g. the date of its acquisition, how the object was acquired and from where, its cultural significance and aspects of its construction, both material and process. This is stored in a museum content management system called EMu [20] which also serves as the AustMus collection register. References to museum documents, scholarly articles and other published materials are also often attached to this record.

However, metadata in the current digital regime is accessible only to curators and museum staff, it partly becomes accessible to the public when/if an object is exhibited in the physical museum or in a bespoke exhibition. Since many of the objects are not exhibited (some have never been, and even fewer can never be exhibited), access to information about culturally significant artifacts is inaccessible to the majority of AustMus stakeholders. Making this information visible is the starting point for the VMP and the record of objects from EMu form the primary sources for the VMP.

AustMus' EMu system derives from a paper-based asset register and is therefore an adaptation of a traditional 18C Western view of the curatorial process which has only limited appeal in the contemporary museum setting. Objects should

Fig. 2. The VMP tagging and browsing interface

be free to be tagged according to native languages, stories and narratives attached or connected to them. Therefore the VMP must circumscribe both the traditional asset management approach to Museology (tangible heritage) and be extensible so that objects are free to have their descriptions grow, connections to be instantiated between them, new intangible knowledge acquired and recorded. This allows the museum's stakeholders to interact with the collection without putting the objects – or for that matter the stakeholders¹ – at risk.

A. Design and Architecture

According to Tom Gruber [22], the Semantic Web “is an ecosystem of interaction among computer systems” and the Virtual Museum of the Pacific (VMP) is intended to facilitate a conversation among its stakeholders. The stakeholders consist of four groups. The museum curators, the custodians of official metadata as well as the physical objects themselves. Pacific Islanders, the rightful owners of the cultural assets including their intangible heritage. Professional researchers, such as anthropologists or other cultural specialists with an interest in the Pacific collection and finally the general public. The conversation between stakeholders occurs on the Web. Each group has the capacity to create new knowledge about the objects, create groups of common interest and provide information to correct or modify the official metadata record. The AustMus curators act as moderators. The development platform for the VMP thus relies on Web technologies (including Web 2.0 and Web Services) and Semantic Web technologies. It differs significantly from other major Web-based museum portals such as Euromuse [19] and Bricks [2] because of its social media capabilities. While there have been general attempts at developing semantic Web infrastructure for museums [16], we believe that advances are made by a focus on understanding the client's business ecosystem rather than on technologies in their own right.

Some stakeholders are skeptical about the VMP, in particular introducing a new technology central to the VMP, concept lattices, always carries risk. Culturally, there are sensitivities about the display on the Web at any price of certain culturally sensitive objects, and breaking the museological tradition of interaction in the physical environment grates with some curators. However, the role of the VMP facilitating dialogue between objects and stakeholders has the opposite effect. The VMP is no substitute for a physical museum experience, it is intended as an entirely new experience. This apparent conflict needs careful stage management in terms of the diffusion of the VMP, incremental, bottom-up and relatively small scale initially. Our first efforts are with 400 objects for this reason.

Further, the project adopts an agile development approach, with whole of system development, unit and iterative usability testing as key aspects of the development life-cycle.

¹Some spears of Pacific Island origin have residual traces of poison on their tips so there are some OH&S issues when handling them.

III. VMP: INTERFACES AND OPERATION

In this section we look at the various management interfaces that allow the VMP to be used extensively by its stakeholders. Our project identifies four groups that require different levels of access to the virtual collection. These are (i) museum curators (ii) anthropologists (and other researchers, such as historians) (iii) indigenous communities (including the traditional cultural owners of the museum artifacts) and (iv) the general public.

Museum curators are the custodians of the collection, they include professional museum managers, domain and preservation experts who all play a role in managing museum assets. In the VMP, responsibility for tangible physical asset management is supplemented by moderating, assessing and expert review of the content created by other stakeholders.

Museum curators also need to apply standards for tagging and annotating and may be required to change, and update existing control vocabularies for their collections. A workflow which enables scalability in performing this moderation is an important aspect of the project deployment.

Anthropologists (and other professional researchers who rely on museum content) are the communities that most benefit from the completeness of a collection that results from a virtual museum. Insights that come from the analysis of a complete collection rather than scattered artifacts observed over time are significant. Professional researchers also play a role in the peer review of existing curatorial tags. As scientific and cultural understandings develop and change, so too the vocabulary for describing artifacts. This community generates and discovers new ways of describing and viewing objects to enhance their understanding.

An important aspect of our work is the diffusion of knowledge about distributed artifacts acquired from the Pacific

Fig. 3. VMP prototype: museum management interface for adding a new image to the collection. Navigation to other management interfaces is via the hyperlinks across the top-frame.

Fig. 4. Adding a new attribute into the VMP prototype system. This allows the vocabulary of tags for describing artifacts to be extended by curators, researchers or indigenous user communities. Existing attributes (tags) are listed in the left frame, a new attribute can be added via the textbox.

(mostly by 19th Century missionaries). Indigenous communities will play a role in the identification of incorrect tags and in the definition and acquisition of new tags.

The VMP should be flexible enough to link artifacts and other rich media, e.g., audio/music. The VMP should also allow narratives – as text, audio or video – from the Pacific to be associated with objects in the collection.

Finally, our system acknowledges that museums have a charter to the public. A fun and educational dimension is that anyone should be able to blog, comment or react/respond to artifacts in the same way that TripAdvisor [23] allows travelers to respond to their experiences when staying at hotels. Supporting the serious amateur researcher will also add enormous value to the virtual collection.

1) *Adding a new Object and Attributes (tags) to the collection:* The VMP provides a content upload interface that allows the museum staff to upload images into the virtual collection. This is shown in Fig. 3.

Likewise, the VMP is an extensible content management system. A management interface is provided to allow stakeholders to extend the vocabulary for tagging the virtual collection shown in Fig. 4. An important idea for the collaboration is that a rigid Western view of the Pacific collections should not be imposed, but rather that the tags be extensible to new, potentially more meaningful descriptors, in any vocabulary and particularly in language other than English.

2) *Editing an Object's Attributes (tags) Individually and by Collection:* Once a new object is added into the VMP, it can be tagged from the attribute control vocabulary. This is shown in Fig. 5. The top most image is highlighted in Fig. 5 and is shown to have the attributes *cane*, *metal*, *other*, *pearl*, *plant*, *weapon* and *wood*. Fig. 6 shows an interface where all the objects with a particular attribute can be shown and edited.

3) *Browsing the Collection:* By including different perspectives the user defines a sub-context in which operations are performed. The user may change this sub-context while browsing, thus obtaining at the present concept further information and search options. If at a given concept a perspective is included (i.e. the set of attributes is increased), then VMP moves to a new concept. This allows the addition of perspectives during the search without information loss. Symmetrically, the user may remove a perspective which takes them to a new concept with more images in the extent.

The VMP uses most of its interface to show thumbnails of images in the extent of the chosen concept (see Fig. 7). The lattice structure around the current concept is represented through the list of upper and lower neighbours which allow the user to move to super- or sub-concepts.

A. Adding Narratives to the Collection

Integrating a wiki with VMP is the first step towards providing user communities – the general public and also indigenous owners – with the ability to add and enhance the virtual collection. Just as in other wiki's the content will need to be moderated and users will be asked to register and verify their identity by email. A real-time RSS-based dashboard

Fig. 5. Editing an object individually in the VMP prototype. The list of all current attributes (tags) for the top-most object in the left frame are listed under "current". The remaining attributes that can be selected are listed under "available" in the right frame.

Fig. 6. Adding or editing an object's attributes in the VMP prototype. In this figure all the objects highlighted (red) have the attribute leaf.

provides immediate feeds on actions taking place. The other management interfaces, such as for adding objects, attributes and perspectives, have more restricted access.

B. Search and Query-By-Example

Browsing is achieved by moving to neighboring concepts. In many cases the user will want to go directly to images having a certain set of attributes. This is offered by the direct search function which enables the use to type attributes into a text field. Another type of search is performed by the query-by-

Fig. 7. VMP: the browsing interface. The collection refined with the attribute pigment. Note the attributes container, raw material and body enhancement.

Fig. 8. VMP prototype wiki. Text can be added to Objects in the collection via the browsing interface. This provides some early functionality required to collect information from the user communities of the virtual museum.

example. Instead of defining a set of attributes, a set of objects is defined as the sample set. The query-by-example function then computes the common attributes of these images (in the selected sub-context) and returns all other images having these attributes. In this way, query-by-example is the dual of the search function. While the search for images having certain attributes is not affected by the removal or addition of perspectives to the sub-context, query-by-example depends on the selected sub-context. The more attributes taken into consideration, the smaller the set of images that have exactly the same attributes as the query example.

C. Concept Similarity

The aim of query-by-example is to find objects which are similar to the objects in a given sample set. This is a narrow understanding of similarity, implying equivalence in the considered sub-context; for the query-by-example function two objects are “similar” in a sub-context. If the objects are uniquely described by the attributes in the chosen sub-context then query-by-example seldom yields new information.

A more general approach is to define a similarity measure for pairs of concepts. In [18] several similarity measures on attribute sets are investigated. Similarity of two objects g and h is then described as the similarity of the attribute sets g' and h' . In order to use the grouping of objects provided by the formal concepts, the VMP works with a similarity measure on semi-concepts which allows the return of a ranked list of similar concepts. The similarity measure is derived from the metrics described in [12] and provide a relevance ranking mechanism.

IV. METADATA MANAGEMENT AND STANDARDS

There are a number of metadata models and standards for museology that are relevant to the VMP. Generic Web-based standards, MPEG-7 for images, XML Schema for data transport, WSDL for Web Services, OWL for knowledge and resource representation, RSS for syndication etc, but also museum-based standards, CIDOC[21] Spectrum[24] and NISO[9].

A. The AustMus Meta-model

As with many museums with historic collections, none of the more general museum-based classifications or standards are followed at AustMus. This is partly due to AustMus being founded in 1827 (Australia’s oldest museum), and the collection being mostly acquired in the 18C and early 19C.

At AustMus, the classification system is based on 17 ‘categories’, 712 ‘items’ and 105 ‘attributes’. Examples of categories are *domicile*, *hunting-fishing-weapon*, *tool*, *raw-material* etc. Items are subtypes of categories for example an *axe* is a *tool*, an *arrow head* is a *hunting fishing weapon*, *wood* is a *raw material*. Attributes are then used partially as a cross-reference to multiple categories, for instance an *axe* is a *tool* but it could also belong in the *hunting fishing weapon* category and could also be used in building, in which case tagged with the attribute *domicile*, itself a category. In many cases attributes are used to extend the description of an object, if a given boomerang belongs to the category of *hunting fishing weapon*, it could also be ceremonially and tagged with the attribute *dance*.

The ‘category-item-attribute’ metadata model used at AustMus is called a ‘thesaurus’ by museum staff but has some important differences to the traditional notion of a thesaurus as we shall later discover. The metamodel is used to categorize the more than 110,000 objects in the ethnographic collections. This collection consists of three distinct groups comprising,

Fig. 9. VMP: A popular way of browsing is to use the current object to find like objects. This is done via by query-by-example, this illustrates another modality for search and discovery in the VMP.

60,000 artifacts from the Pacific (representing 50% of the AustMus collection), Indigenous Australian artifacts (33% or 40,000) and a further 17% of the collection derived from Asia, Africa and the Americas (10,000). The AustMus also looks after approximately 1 million archaeological specimens and maintain a huge biological collection but these objects are presently beyond the scope of the VMP.

B. The Museum Metadata-model Ecosystem

One of the first analysis tasks for the VMP was to come to terms with the AustMus 'thesaurus'. This involved understanding it as a metadata model – so that the technical team could engineer a suitable internal data model for the VMP – but also understand the way that the metadata model evolved as an insight to AustMus' business process model. This insight is necessary for backward compatibility with the existing content management system, but important so that the VMP is extensible to new and developing museum standards [21] as well as thematic tagging from indigenous experts and specialist researchers.

There is therefore, to extend the ecosystem metaphor, a metadata-model ecosystem representing the classic Western museological record as it took root in Australia from 1827 and evolved into the thesaurus which was established in the early 1990s. The simplest explanation is that the 'thesaurus' was designed from keywords usage in the AustMus register: a literary warrant system that has become a corporate warrant classification system.

This mandates a similar philosophy in the metadata-model ecosystem of the VMP. Communities of users should be able to define their own metadata tags and semantic structures according to their interest, this being the way the AustMus thesaurus itself developed. An obvious example is knowledge capture of native words for given objects, this expertise resides primarily with indigenous community members. Another, specialist researchers concentrating on the Pacific can define their own semantic themes (exhibitions), link objects, connect and annotate them with rich multimedia or narratives.

To investigate this, we took several objects from the museum's EMu content management system and worked them

Fig. 11. The Digital Ecosystem of the Virtual Museum of the Pacific.

back into the paper-based register, an example is shown in Fig. 10. From this we could work forward to see how objects had been classified in the 'thesaurus' and therefore how the metadata in EMu had been assigned. For instance, an important item type is an *axe*, which has been normalized from *ax*, *hatchet* or *tomahawk*. In this way the AustMus thesaurus is properly a control vocabulary: it does not extend a word with synonyms or hypernyms as a thesaurus does but rather restricts the descriptive term to normalize the control.

V. SEMANTIC CONCEPTS AND ONTOLOGIES

To understand how the VMP can be viewed as a digital ecosystem, we consider its semantic concepts and the ontology of the Digital Ecosystem [3] to situate our work according to the standard references and refer to Fig. 11

Individuation – although abstractions from real world objects, the digital objects in the VMP are individuals, most commonly these are high-resolution images.

The digital objects are themselves multi-faceted, a single real-world object is represented by several digital images (representing various views of the object and sometimes 3D scans) and may contain various metadata tags, for example a given digital object might include the attributes 'pine', 'stone' and 'shell'. Attributes are themselves aggregated, so that 'pine' is a subclass of 'wood' – this builds a containment hierarchy. Likewise, an attribute as a location has a natural containment hierarchy, so the 'Tanga Group' of islands is part of 'New Ireland Province' which in turn is part of 'Papua New Guinea' which is a part of 'Melanesia'. Attributes can therefore be individuals when they are leaf nodes in the attribute hierarchy. Likewise, users of the VMP are individuals.

Packet Level – the act of tagging an attribute to an object is a packet, this itself can be an act derived from a control vocabulary of attributes via the free definition of an attribute to be used as a tag by a user. Perspectives too are packets, for example the 'raw material' perspective might include the attributes 'wood', 'stone', 'shell', 'metal' and 'charcoal' that help describe what an object is made of. Likewise, the creation of a story or narrative via the wiki describes a packet as does associating one digital object with another or with rich multimedia. A user is associated with a group – this is also a packet – e.g. curator, director, public or indigenous community member.

1971		REGISTER OF		ETHNOLOGY	
Date	Registration No.	No. of Specimens	Name or Description	Locality	How acquired
E:					
22	65084	1	FISH HOOK, CLAM & TURTLE SHELL 11cm.	FINLAND, N.G.	See E. 65084 for details
	5	1	" " " " " "	SOLOMON IS.	
	6	1	FISH HOOK, PEARL SHELL & BONE 8cm.	HAWAII	
	7	1	" " " " " "	GABERT IS.	
	8	1	" " " " " "	SOLOMON IS.	
	9	1	PEARL SHELL & PEARL SHELL WITH STONE ATTACHED	ELLICE IS.	
	65090	1	PEARL SHELL & TURTLE SHELL 7cm.	SOLOMON IS. (RUMUVAI)	
	1	1	" " " " " "	" " "	
	2	1	" " " " " "	" " "	
	3	1	" " " " " "	" " "	
	4	1	" " " " " "	" " "	
	5	1	" " " " " "	" " "	
			CLAM SHELL & TURTLE SHELL 16cm.	FINLAND IS.	

Fig. 10. Extract from the AustMus register – entries from 1971.

Context – the arrangement of digital objects within a formal concept indicates all relevant objects within that context. Context then has several meanings in the VMP, the context of the collection, say the 400 objects selected from over 110,000. Also, the search, browsing or navigation context, take for instance the Web services call `getConcept.php?attributes=pacific+polynesia+samoa+wood`. This might return five objects that satisfy the attributes ‘pacific’, ‘polynesia’, ‘samoa’ and ‘wood’. The induced formal concept is a context. So too, a ‘perspective’ is a context because it represents a many-valued context in the theory of formal concept analysis [25].

Ecosystem – the information space pertaining to the Aust-Mus’ 400 objects in the VMP is an ecosystem but more more ambitiously, multiple, linked museums sharing the same control vocabulary form the infrastructure of a more extensive digital ecosystem. Similarly, the stakeholders all represent ecosystems of related interest.

Cross-Ecosystem Relationships – any inferences that are formed as a result of user communities tagging and annotating objects (or writing wiki entries) in their own group, represent relationships across ecosystems. For example, historians, anthropologists and curators are each members of their own ‘group’. If Anthropologists are a group within their own ‘ecosystem’ and the historians belong to another, a cross-ecosystem relationship is formed from their respective collaborative inputs into the VMP.

VI. CONCLUSION

In this paper we have described the Virtual Museum of the Pacific as a digital ecosystem in which objects of a digital collection of museum artifacts are derived from facets of the physical artifacts held in the Australian Museum’s Pacific Collection. The Virtual Museum of the Pacific allows several diverse search methods: attribute search based on a control vocabulary, search via query refinement and query-by-example. The system provides a number of management interfaces that enable content to be added and tagged, the control vocabulary to be extended, user perspectives to be defined and narratives added via a wiki. We describe the design of the Virtual Museum of the Pacific as a semantic Web application with a Formal Concept Analysis Web service engine. We identify elements of the digital ecosystem by purpose, function and stakeholder. We describe and offer solutions to digital ecosystems design in terms of the deployment, the technological platform, the historical context of the growth of the collection and the challenges faced in the implementation of an extensible virtual museum metadata model.

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