Online Virtual Exhibitions: Concepts and Design Considerations

Schubert Foo

College of Humanities, Arts and Social Sciences
Nanyang Technological University, Nanyang Link, Singapore
E-mail: sfoo@pmail.ntu.edu.sg

ABSTRACT

Online virtual exhibitions (VEs) are acknowledged as important complimentary counterparts to physical exhibitions. It overcomes space, time and location restrictions and allows global visitors to access these priceless and exciting treasures that are stored in museums, archives and other institutions on a 24/7/365 basis. Well constructed VEs can offer alternative experiences to the "real thing" and open up other opportunities that include learning, more content beyond physical exhibits, active participation and contribution by visitors through forums and uploads, online shopping, and others. This paper provides a state-of-the-art review, and illustrates concepts and design considerations for the development of VEs that can be highly effective and efficient with minimal technological knowledge. By considering the important issues of metadata, system architecture design and development techniques, it becomes possible to generate a series of VEs to meet the needs of different user groups and at the same time cater to the constraints of the client computers, thereby providing the users the best possible experience in engaging with the VEs.

Keywords: Online virtual exhibitions, VE concepts, VE design.

1. INTRODUCTION

An early definition of virtual exhibition (VE) is defined as an online Web-based hyper-textual dynamic collections devoted to a specific theme, topic, concept or idea[1]. Most virtual exhibitions are attributed to museums and archives to make visible their collections to end users, generally the public or specialised user groups[2]. Original artifacts are digitally captured and rendered into 2-D or 3-D objects which are packaged together and linked by hyperlinks to allow non-linearity or multiple-linearity by users (exhibition visitors). Virtual exhibitions are viewed as dynamic as they often undergo ongoing change in terms of design, activity and content, including encouraging users to contribute towards it, thereby adding to its dynamism. Many early VEs are undertaken as distinct projects and packaged as stand-alone exhibits with little regard on the reusability of objects, adoption of standards to support interoperability, extensible and scalable system architectures to support growth

and pervasiveness of exhibitions. Some examples of early VEs include Building a National Collection: 150 Years of Print Collecting at the Smithsonian by the National Museum of American History (americanhistory.si.edu/prints/index.htm); American History Documents (www.indiana.edu/~liblilly/history/history.html); Birds: A Virtual Exhibition by Canadian Heritage Information Network (www.virtualmuseum.ca/Exhibitions/Birds/Birds/); Colours of the Wind by the National Archives of Singapore (www.a2o.com.sg/a2o/public/html/online_exhibit/misas/exhibit/index2.html)[3,4] and others.

Over the last decade, improvements to these areas have been seen and VEs have reached a stage of sophistication although a number of fundamental challenges remain. While the basic tenets of VE have not changed, it is helpful to provide an updated definition of VE:

A VE is a Web-based hypermedia collection of captured or rendered multi-dimensional information

objects, possibly stored in distributed networks, designed around a specific theme, topic, concept or idea, and harnessed with state-of-art technology and architecture to deliver a user-centered and engaging experience of discovery, learning, contributing and being entertained through its nature of its dynamic product and service offerings.

The case for investing in the design and development of VE has been well documented[5,6]. First and foremost is the recognition that hosting VEs provides a gateway to showcase museum or archive (hereafter referred to as institution) collections that are not bound by time (temporal), distance (spatial) and space (spatial) constraints unlike physical exhibitions. This addresses the important issue to make valuable artifacts available to the masses while playing the role of custodianship of national and international treasures.

Users are unlikely to pay visits to these institutions unless they are aware of its collections and holdings. VEs coupled with educational functionality can promote the institution as a centre for learning and encourage users to visit and access more artifacts via information objects. Such demonstration of the institutional relevance and societal value through a strong public profile and high usage figures can be used to help secure adequate funding and resources for survival, sustainability and growth into the future. As such, outreach through VEs is seen to be an important strategic activity that needs to be properly planned and executed. Other forms of outreach activities like publications, websites, tours, talks, demonstrations and other activities can be undertaken alongside VEs to create the impact and yield the desired outcomes.

Online strategies (VEs and websites) have particular advantages: it is relatively easy to add new products and services or revamp existing ones in the form of adding new materials, updating and reusing existing materials, adding new learning and edutainment components, online shopping, online forums, users' contributions, to name just a few. VEs, through digitisation and rendering, also have the distinct advantage to create and use electronic surrogates of original fragile or sensitive records, or priceless artifacts which might otherwise be damaged in physical consultation. Established institutions such as Smithsonian Institute (www.si.edu), Auckland Art Museum (www.ackland.org/index.php), and most national heritage boards and museums around the world have a permanent and rich set of VEs hosted on their servers. Collectively, they are able to display and make available a significant amount of "treasures" held by the institution which is by far much than what physical exhibitions can display and achieve

at any one time. This means of extending outreach has significant long term returns of investment once these VEs are curated and implemented for public access and use.

While VEs have been critiqued in the past for their inability to provide the experience of the real thing, VEs can allow users to understand, discover, learn and do far more than physical exhibitions. By adopting a carefully researched user-centered design, VEs through hyper-linking supports both linear and non-linear discovery and learning pathways, creating learning opportunities that are difficult to replicate in physical exhibitions. The ability to engage in multiple forms of media (text, image, audio, sound, video, augmented reality and virtual reality components) on one page, having the ability to reverse, revisit, translate and read text tailored for different user groups, proficiencies and requirements, immersion in well crafted theme-games, etc. collective helps to establish a deeper sense of understanding, awareness, and learning of contents than physical exhibits. VEs are therefore no longer viewed as passing fads but an important logical companion and extension to physical exhibitions.

Beth Hatefutsoth, the Nahum Goldmann Museum of the Jewish Diaspora (http://www.bh.org.il/index.html) site has many VEs on Jewish people in various places available in both in English and Hebrew. British Library VEs on various topics (http://www. collectbritain.co.uk/galleries/); National Gallery of Art's VEs (http://www.nga.gov/exhibitions/webtours. shtm) based on Apple QuickTime VT; VE of Canadian birds(http://www.virtualmuseum.ca/Exhibitions/Birds/ Birds/); Cabaret Mechanical Theatre's VE (http:// www.cabaret.co.uk/vrexs.htm); Everyone's VE (http: //billdouglas.ex.ac.uk/eve/ exhibitions.asp); International Institute of Social History's VEs (http://www.iisg.nl/ exhibitions/); Water and the Sacred, a photographic exhibition by Claude Renault available at Charnwood Museum VEs site (http://www.kalakahani.co.uk/ crenault/); National Library Board of Singapore's VEs (http://exhibitions.nlb.gov.sg/); Musee McCord Museum's VEs (http://www.mccord-museum.qc.ca/ en/keys/virtualexhibits/); and Museum and Art Gallery of the Northern Territory (http://www.nt.gov.au/nreta/ museums/virtual/index.html). These are some of the important VEs, but there are obviously many more that are meant for general public and available on Internet. Some of the developers of these exhibitions added virtual reality or Flash movies but most of them are designed using images with some animation, and adequate textual information to relay the content and support the explanation of the objects and events in the exhibits.

While the discussion of VEs has so far being related to non-profit institutions such as museums and archives, it should be borne in mind that the ideas put forth subsequently are equally applicable to profit organisations for the marketing of its products and services.

While some functionality and features are no longer slanted towards the social responsibility aspects, these VEs still relies on similar characteristics such as the ability to deliver attractive, interesting, engaging, and intriguing "exhibits" through user-friendly interfaces to encourage users (buyers) to visit and access the site, and ultimately become customers of the organisation. These sites typically have the common features of hyper-animated graphics, brief exhibitions and high interactivity zones to showcase products and services, online areas for mailing list sign-ups and online stores to order and make purchases. These VEs are often associated with biased education in an attempt to gain competitive advantage over other competitors' VE sites. On the other hand, VEs developed by non-profit organisations and government agencies are constructed with different objectives in mind: archival, preservation, discovery, education, and others. They are deemed more authoritative; contain better researched and trusted resources, and higher educational value.

Nonetheless, a similar set of user-centered design paradigms, use of technological tools, well designed system architectures to high level of automation with minimal human intervention and effort to create new versions of VEs are equally applicable for profit organisations as for non-profit organisations where VEs are becoming pervasive. At a higher abstract level, we may consider VEs as digital libraries (DLs) that contain a set of information objects that can be accessed individually, or packaged together by applications supported by the DLs. The Digital Library Federation defines digital libraries as "organisations that provide the resources, including the specialised staff, to select, structure, offer intellectual access to, interpret, distribute, preserve the integrity of, and ensure the persistence over time of collections of digital works so that they are readily available for use by a defined community or set of communities" (www.diglib.org/about/dldefinition.htm). This effectively parallels what VEs attempt to provide to users through its contents, features and services.

The importance of educational digital libraries such as Alexandria Digital Library (www. alexandria. ucsb.edu/), National Science Digital Library (http://nsdl.org/), the eGranary Digital Library (www. widernet.org/digitalLibrary/), Second Life (http://

secondlife.com/) and other similar online virtual communities have also demonstrated the use of virtual worlds for learning. Recently, Giunti Labs, one of Europe's leading vendor of elearning and mobile learning content solutions proposed a new system, eXact VLW (virtual Learning Worlds) that encompass an authoring environment, to create, manage and deliver 3-D objects, artifacts and scenes within collaborative virtual learning worlds compatible with SCORM (an eLearning standard). No technical knowledge of VRML, X3D or any other 3-D programming language are needed to create virtual learning experiences that can be integrated into existing LMS (Learning Management Systems) or VLE (virtual learning environment) through SCORM. Originally developed for education in digital heritage, the system allows 2-D images, videos, text and any standard SCO learning objects (all adhering to open standards and tracking protocols) to be used to create VEs and virtual learning worlds [7].

The aim of this conceptual paper is to treat VEs from this generic angle of varying applicability to examine a number of pertinent issues in the design and delivery of online exhibitions. This includes addressing the stakeholders of VEs, the important role of metadata, system architectural design, and research advances of techniques and tools. This is done by drawing upon relevant literature of DL and VE researches. A deliberate omission of this paper is a detailed treatise of exhibition content (selection, organisation, and packaging) which is an area in its own right.

2. STAKEHOLDERS OF VIRTUAL EXHIBITIONS

A first cursory thought on stakeholders of VEs might perhaps result in the thinking that only two groups exist: that of the exhibition designer and end users. This is in fact quite contrary to reality. Patel, *et al.* suggested that there are actually six groups of stakeholders involved in the process of creating and using the VE, with each group playing different roles [8]. The stakeholders are (i) curator who is knowledgeable of the information objections and primarily responsible for artifact selection (i.e. identifying and selecting the artifacts for the VE); (ii) photographer who is responsible for digital acquisition to create the information objects to be stored in the digital repository; (iii) cataloguer who is responsible for data management to describe, catalogue and group individual objects together; (iv) modeller who is responsible for model refinement to create and describe object interpretations and/or refinements; (v) curator exhibition designer who is responsible for exhibition building; and (vi) end user who is consumer of the final VE [8].

The first five categories of stakeholders are typically part of the VE team, each with a different set of knowledge, expertise and skill sets and differing metadata requirements. VE teams can be large and can comprise professional writers, artists, archivists, graphic designers, multimedia technicians, technical specialists and curators. External advisory and editorial committees may also be roped in the VE design and construction to create a more balanced and effective exhibition.

End users, on the other hand, can evolve from a myriad of different user groups: children and adults, students and teachers, academics and researchers, novice and expert users, tourists and casual Internet surfers, the general public and professional users (such as archivists, librarians and information professionals).

This big range of stakeholders collectively translates into a huge set of differing requirements and expectations throughout the process of designing, developing and using the exhibition. A one size fits all paradigm is almost certain to fail to meet these expectations. There is a need for good metadata design and management, novel and effective ways to generate different versions of VEs at least or acceptable costs and high productivity in order to satisfy the needs of different user groups. With this, we can expect to find the requirement to tailor varying levels of content generation and online media types to cater to the needs of different types of users; contents would typically include multimedia elements, 2-D, 3-D, augmented reality (AR) and virtual reality (VR)[9,10].

3. METADATA REQUIREMENTS

Metadata has always been an extremely crucial aspect for describing and managing artifacts in the collection. When these are digitally acquired and transformed into information objects, a new set of corresponding metadata becomes necessary. When new applications such as VEs are developed, more metadata is required to describe and manage the exhibition, page contents, access information, and so on. The different stakeholder groups in the previous section provide an idea of the wide ranging metadata requirements needed by various constituents of the cultural heritage industry. The active researches done on metadata and continuing developments of standards such as SPECTRUM, EAD, Dublin Core and other metadata schemes attest to the importance of having relevant metadata to support a variety of needs. Metadata can typically be classified as descriptive metadata, technical metadata, presentation metadata, preservation metadata, administrative metadata, and

resource discovery metadata. It should be noted that while Dublin Core is an important, well-established metadata standard for descriptive and resource discovery across domains and used by almost all the systems, but it does not specifically deals with museum, archive and education requirements that have their own set of detailed metadata elements.

This overwhelming amount of metadata has prompted the proposal for having a system for authoring, maintaining and managing metadata to support the development of the Augmented Representation of Cultural Objects (ARCO) system for museums to create, manipulate, manage and present small to medium artifacts in VEs for both internally within museums and externally on the Web[8]. They envisaged the creation of digital artifacts providing opportunities to develop virtual learning environments (VLEs) which in turn entail creating new additional metadata such as those defined by ADL Sharable Content Object Reference Model (SCORM) or IEEE Learning Object Metadata (LOM) standards to support eLearning. Furthermore, they envisage commercial exploitation by institutions in the form of virtual loans for VEs (through information objects) that requires the support of a digital rights management system (DRMS). All this translates into more and more need for metadata.

Two issues are particularly important for metadata in the context of VEs. First is the highly recommended use of standards to support interoperability. When this becomes not possible for whatever reasons, the exchange of metadata information across systems becomes more costly due to the need for validation, optimisation and mapping. In terms of metadata definition and storage, XML has turned out to be the de-facto emerging preferred means to manage information objects and VEs. VE exhibition pages contain a series of exhibition objects that can be neatly encapsulated in a XML-based conceptual hypermedia document model. Such a document typically includes different types of information: text, data, graphics, images, hyperlinks and other elements. Likewise, the information object's metadata can be neatly based on the XML structure. Effectively, an XML-based solution exhibits the advantages such as platform independence, clear structuring and encapsulation, modularity, and so on.

The second issue pertains to the need to create a range of representations for one same original artifact. As an example, an image can be captured at different resolutions and sizes. They can be used as thumbnails, medium resolution for browsing, and very high resolution for zooming and detailed analysis. These different versions of content basically share

the same metadata except for those entities that are distinct and different.

Figure 1 shows an example of a photograph metadata set in XML format[9]. In this example, the Accession ID is used to uniquely identify a photograph artifact while the location element is used to define the repository directory where all the images are stored. As indicated previously, the image element can be defined more than once to cater to the different available versions of the same original photograph. These versions may contain resized, enhanced, or digitally-manipulated variations (e.g. colour, addition of borders) of the original photograph.

The same approach can be adopted for textual artifact metadata to incorporate the standard Dublin Core elements plus text specific elements. For example, the "content_version" element can be used for the support layering of information through different descriptive layers of a textual artifact. These text descriptions can range from summarised abstract information to detailed information, or specially text written for children or adults, and so on. Likewise we can adopt the same approach for different audio, video and other artifacts to cater for different network

conditions, resolutions, and the like. In doing so, we have one associated metadata record across different content versions that can be drawn by the VE to create a series of VEs for different users.

4. CREATION OF MULTIPLE VERSIONS OF VES EFFECTIVELY AND EFFICIENTLY

By using this approach of layering metadata and use of style-sheets, Lim and Foo[9] developed a VE authoring system to interface with the National Archives of Singapore digital archive to support the creation of VEs. The XML-based digital archive provides different artifact types that form the contents in the exhibition through the reference and reuse model. This means that only one copy of information object resides in the repository which is in turn referenced and used by more than one VE as necessary. Information objects and exhibitions are endowed with rich metadata that include the Dublin Core elements and other new attributes to support enhanced search support for field and free text searches. An authoring tool using a grid-layout approach is used to define and layout the exhibition contents. XML's Cascading Style Sheet

```
<?xml version = "1.0" encoding = "UTF-8">
<!DOCTYPE photo [
<!ELEMENT photo (title*, creator*, subject*, description*,  contributor*, date*, type*, format, accession_id, source*,
        language*, relation*, coverage*, copyright*, identifier*, location, image+)>
        <!ELEMENT title (#PCDATA)>
        <!ELEMENT creator (#PCDATA)>
        <!ELEMENT subject (#PCDATA)>
        <!ELEMENT description (#PCDATA)>
        <!ELEMENT contributor (#PCDATA)>
        <!ELEMENT date (#PCDATA)>              Standard Dublin Core 15 metadata
        <!ELEMENT type (#PCDATA)>              elements
        <!ELEMENT format (#PCDATA)>
        <!ELEMENT accession_id (#PCDATA)>
        <!ELEMENT source (#PCDATA)>
        <!ELEMENT language (#PCDATA)>
        <!ELEMENT relation (#PCDATA)>
        <!ELEMENT coverage (#PCDATA)>
        <!ELEMENT copyright (#PCDATA)>
        <!ELEMENT identifier (#PCDATA)>
        <!ELEMENT location (#PCDATA)>
        <!ELEMENT image (img_id, img_height?, img_width?, img_file_size?, img_description?,
        reproduction_date?, photoCD?, photoCD_imgno?)
            <!ELEMENT img_no (#PCDATA)>
            <!ELEMENT photo_size (#PCDATA)>
            <!ELEMENT img_height (#PCDATA)>
            <!ELEMENT img_width (#PCDATA)>          Additional metadata
            <!ELEMENT img_file_size (#PCDATA)>       for photograph artifact
            <!ELEMENT img_description (#PCDATA)>
            <!ELEMENT reproduction_date (#PCDATA)>
            <!ELEMENT photoCD (#PCDATA)>
            <!ELEMENT photoCD_imgno(#PCDATA)>
    ]>
```

Figure 1. Example of photograph metadata document type definition[9].

(CSS) and Extended Style Sheets (XSL) are then selected from a range of predefined templates and applied to the XML documents to yield the final VE in HTML format. By adopting the notion of information layering in the descriptors or different editions of the information objects, and the application of different style sheets, it becomes possible to create multiple versions of the same exhibition that varies in content, layout and interface to create different versions of VEs for different user groups. The use of style sheets is particularly useful as it allows content and structure to be separated cleanly so that the information can rendered to yield different look-and-feel interface versions of VEs, thereby enhancing the productivity of creating VEs and updating existing VEs. A second version of this system was subsequently developed[11] to enhance the authoring aspect by supporting a WYSIWYG interface for VE content layout and addition of different information objects types.

A similar approach was also adopted by Cruz-Lara, et al.[12] in the development of a distributed content management framework for digital museums based on XML and XSL techniques. Using this framework, they developed a Lanyu Digital Museum for the Lanyu Island and its Yami inhabitants, and a Lanyu Virtual Exhibition Hall. In a related article Hong, et al.[13] proposed an intelligent styling system to help museums efficiently and effectively produce and publish attractive VEs through the use of loosely coupled fine-grained style modules (FGSM) to present specific content fragments coupled with a hypermedia authoring system.

5. SYSTEM ARCHITECTURES FOR VES

At the formative stages of VE development, we witness the emergence of different stand-alone proprietary systems as one would expect. Over a period of time, there is a growing emergence of acceptance of standards and techniques, notably in the areas of metadata definition for VE artifacts, XML for storing metadata and exhibition data, utilisation of style templates for generating versions of VEs, and inclusion of eLearning functionality in VEs.

Examples of different system architectures have been report in literature. Figures 2 to 5 show the system architecture for Virtual Exhibition System (VES) by Lim and Foo[9], Virtual Archive Exhibition System (VAES) by Yang, Chennupati and Foo[11], the Lanyu Digital Museum architecture and proposed framework for an integrated digital museum system by Hong, et al.[14]

In VES (Fig. 2), an Artifact Metadata Tool is provided for the exhibition team to re-use or create and store the different artifact objects used in the exhibition. Different repositories are used to store different artifact types and indexed via the XML server to facilitate searching and retrieval of artifacts and exhibition data by the information retrieval engine that is actually part of the functionality of the XML server. After determining the content of the exhibition, the exhibition team organises and lays out the various exhibition pages and defines the objects in each page using the Virtual Exhibition Authoring Tool. This tool is used to create the exhibition metadata and HTML exhibition pages. The exhibition page content includes references to the different artifacts. In VES, the exhibition content is kept separate from page formatting and layout. Exhibitions content is described using XML while formatting, and layout templates in the form of CSS and XSL are used. CSS provide display related information such as table height and width, font definitions, colours for web pages, and so on. XSL is used to format the artifact and exhibition's XML documents into HTML pages for display in Web browsers. Formatting is also applied to each retrieved artifact, which provides exhibition visitors detailed information of an artifact upon demand.

As mentioned earlier, the separation of content and format facilitates the reusability of exhibition's content. Multiple exhibitions may make reference to the same content and since content is separated from the formatting information, the reused content remains intact. New formatting templates may be applied to the reused content creating exhibitions with the same or similar content but different presentation style. Information layering is also possible with the use of XSL templates. The XSL template applied to the XML document may determine which specific information to pull and display based on the needs of the visitors thereby creating exhibitions with different levels of information been displayed. In interacting with virtual exhibits, visitors can also optionally utilise the Exhibition Search Tool to search for information in these exhibitions. The search tool is actually a stand-alone application that allows searching for all the indexed information via the XML server. Searches can be done for specific occurrence of particular artifacts in the exhibitions, as well as exhibition and artifact related information that are stored in the repositories. The matching search results are retrieved from the different repositories and formatted for display. The search output makes direct reference to the exhibition's HTML pages and artifact detailed HTML
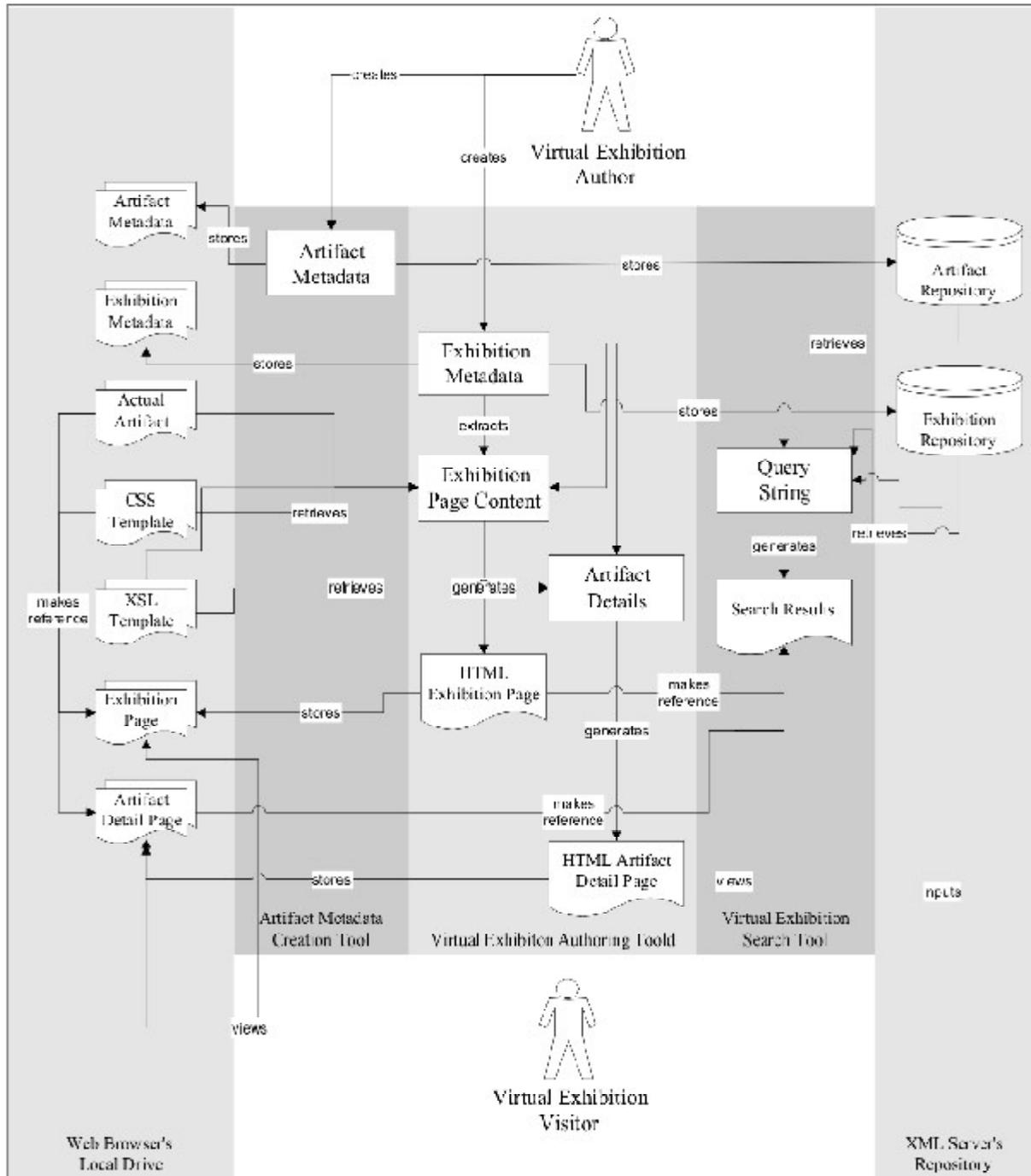
Figure 2. Virtual exhibition system processes and architecture[9].

pages. The later caters to the same artifact being used across a number of different exhibitions.

The VAES (Fig. 3) is an improved version of the original VES (Fig. 2). VAES inherited all the features and provisions of VES and provides a number of enhancements and new features. It extends the artifact types by supporting audio and video. In order to accommodate different resource constraints (Internet connections and available bandwidths), the content

of each audio/video is stored in three versions with varying compression rates. An optimised metadata creation tool, comprising metadata creation, editing and extracting functionality, allows user to define and save the exhibition metadata into the database through a few entry forms. A user-type element is used to identify the unique version for different user groups. The Virtual Exhibition Authoring Tool in VAES supports direct WYSIWYG manipulation for authoring in comparison to using a grid layout definition in the
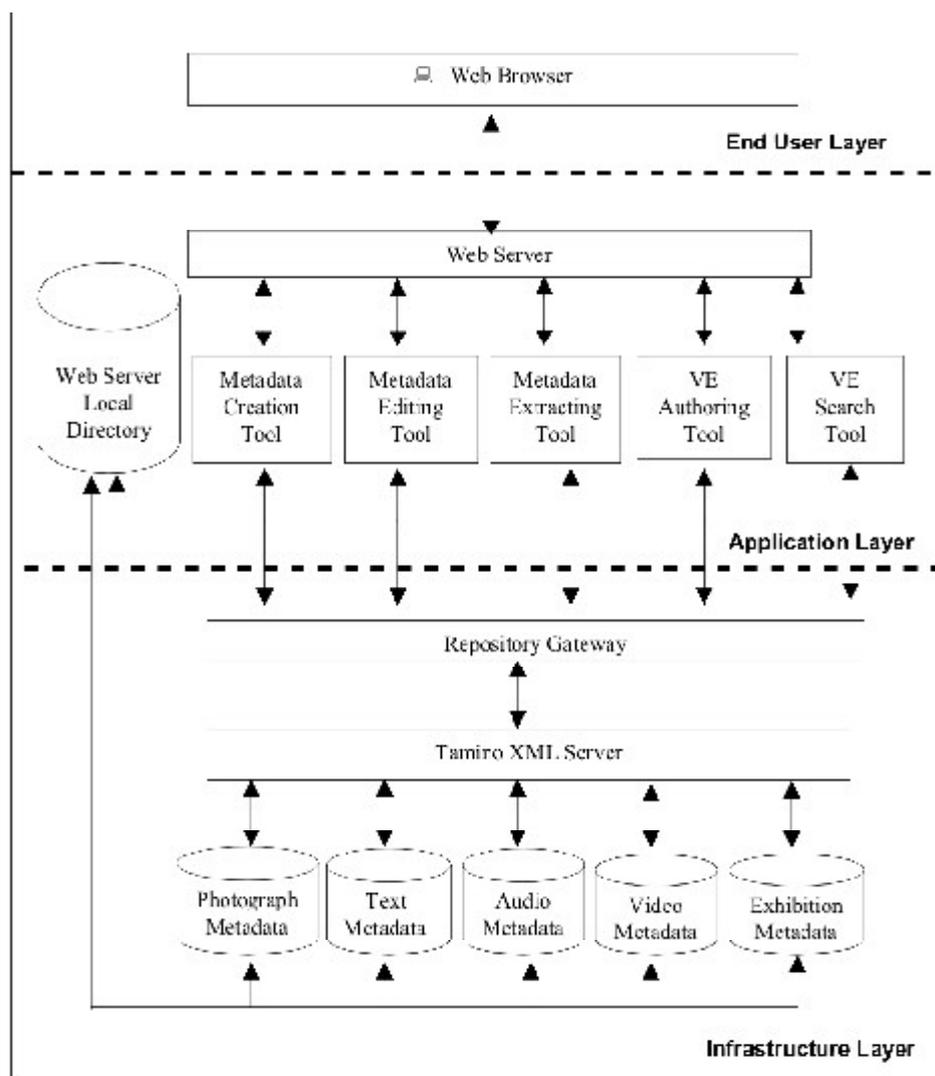
Figure 3. Virtual archive exhibition system architecture[11].

original VES. VAES facilitates the creation of multiple versions of the same exhibition with customised information and in adaptive presentation to support different user profiles to accommodate diverse user groups.

In the Lanyu Digital Museum (Fig. 4), the digital archives contain the various digitised information objects that are described using metadata based on Dublin Core. A database management system (DMS) is used to support creating, viewing, editing, storing and retrieving information objects. A VE is achieved through using the set of XML Exhibition Element Authoring and XSL Authoring tools. The authoring tool is integrated with the digital archive for ease of accessing information objects for use in the VE. In order to facilitate the design and use of XSL templates, exhibition pages were simplified to contain the title, descriptive text, and linkages of sequence of information objects. The Navigation Path Authoring tool defines

the hyperlinks that represent ancestor nodes, descendant nodes, and collateral nodes for each exhibition page that are subsequently assembled to yield the VE navigation map. Using this approach, exhibition pages can be assembled into different exhibition navigation maps without having to modify the exhibition page contents. The XSL authoring allows the exhibition team to define various background music, image and media effects for the exhibition pages. These are then rendered by the XSLT processor to yield the final VE pages. End users interact with the system via the navigation maps that lead them to the various VE pages. Different XSL documents were manually authored in the system and classified under three categories: high-bandwidth adult version; high bandwidth child version; and low bandwidth version. The high-bandwidth adult VE usually take the form of narrated multimedia online slides shows. The high-bandwidth child uses more interesting graphical
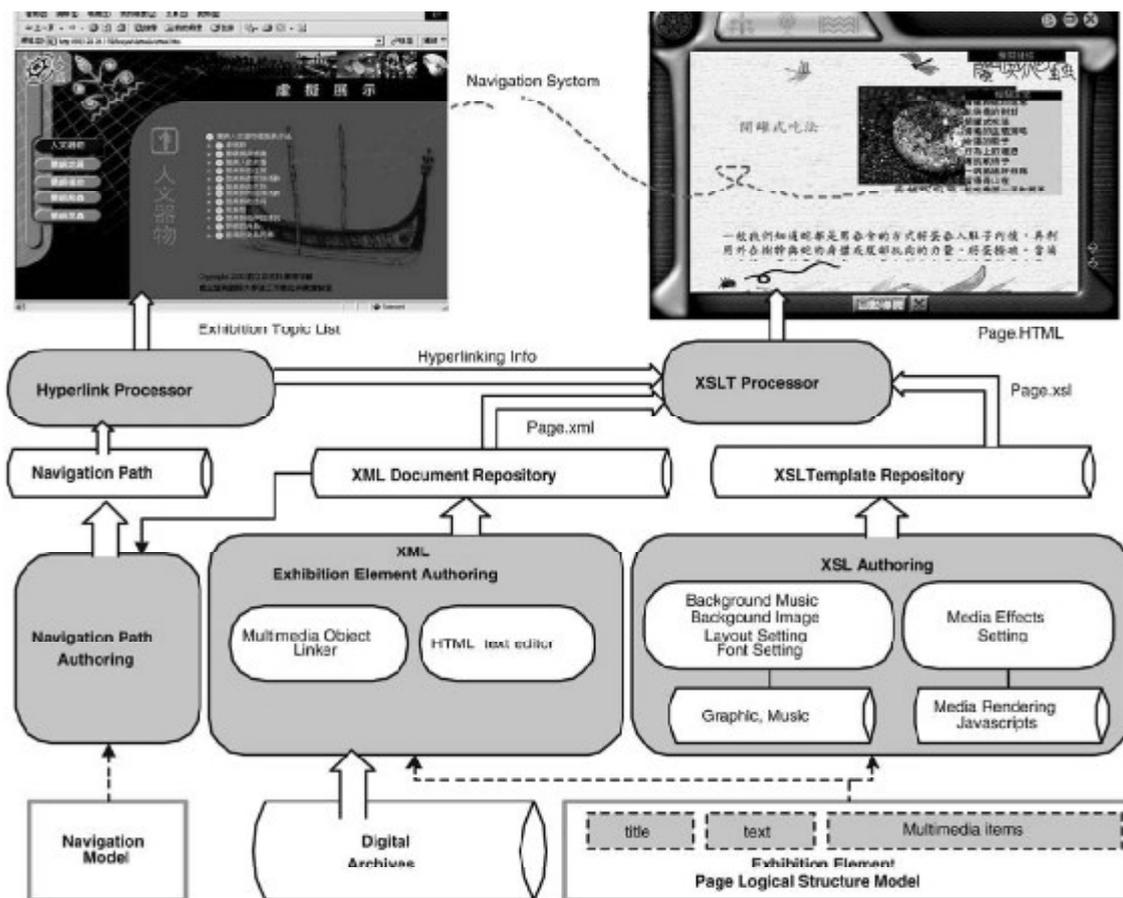
Figure 4. Lanyu digital museum architecture[14].

interfaces with larger fonts and more amusing narrations. Both these versions provide an auto navigation function to automatically run through the VE pages. Finally, the low-bandwidth version uses still pages with little visual elements to reduce.

In the same paper Hong, *et al.*[14] (Fig. 5) proposed an integrated architecture to support the authoring of hypermedia exhibitions, online courses, and educative games, all with a certain level of adaptabilities. The main motivation for development of such a system was to reduce construction and maintenance costs of digital museum websites. The metadata of the information objects are based on CIDOC CRM (Conceptual Reference Model, http://cidoc.ics.forth.gr/) that acts as ontology in cultural heritage applications. For the online learning environment in the system, the authors aim to incorporate adaptive mechanisms for navigation, content, and presentation.

Exhibition and assessment pages will be serialised in XML based on the respective documents logical structure models. Learning objects metadata, based on LOM, will be used to describe primitive learning objects that will serve as building blocks for online courses, and to be used in different learning contexts.

Different user profiles are processed by an adaptive engine to create pages that are customised in style, navigation and contents.

Although these and many current VE applications have adopted different system architecture for their systems, they tend to share a number of basic components to support VE functionality. Figure 6 attempts to encapsulate a generic system architecture derived from existing literature that can be used as a useful platform for the development of VE systems in future. The architecture aims to support effectiveness and efficiency in generating, maintaining and managing VEs. It attempts to provide VE exhibition teams' useful tool sets to generate different versions of the same VEs for end users' consumption, taking into account user needs and a system constraint of the client's set up in accessing the exhibition.

The primitive data level contains all the information objects that can be used for VEs: text, image, audio, video, 3-D graphics, interactive media, and so on. These information objects can be different versions of digitised artifacts or born digital objects. When eLearning is considered, this can also include questions for quizzes for assessment, and other
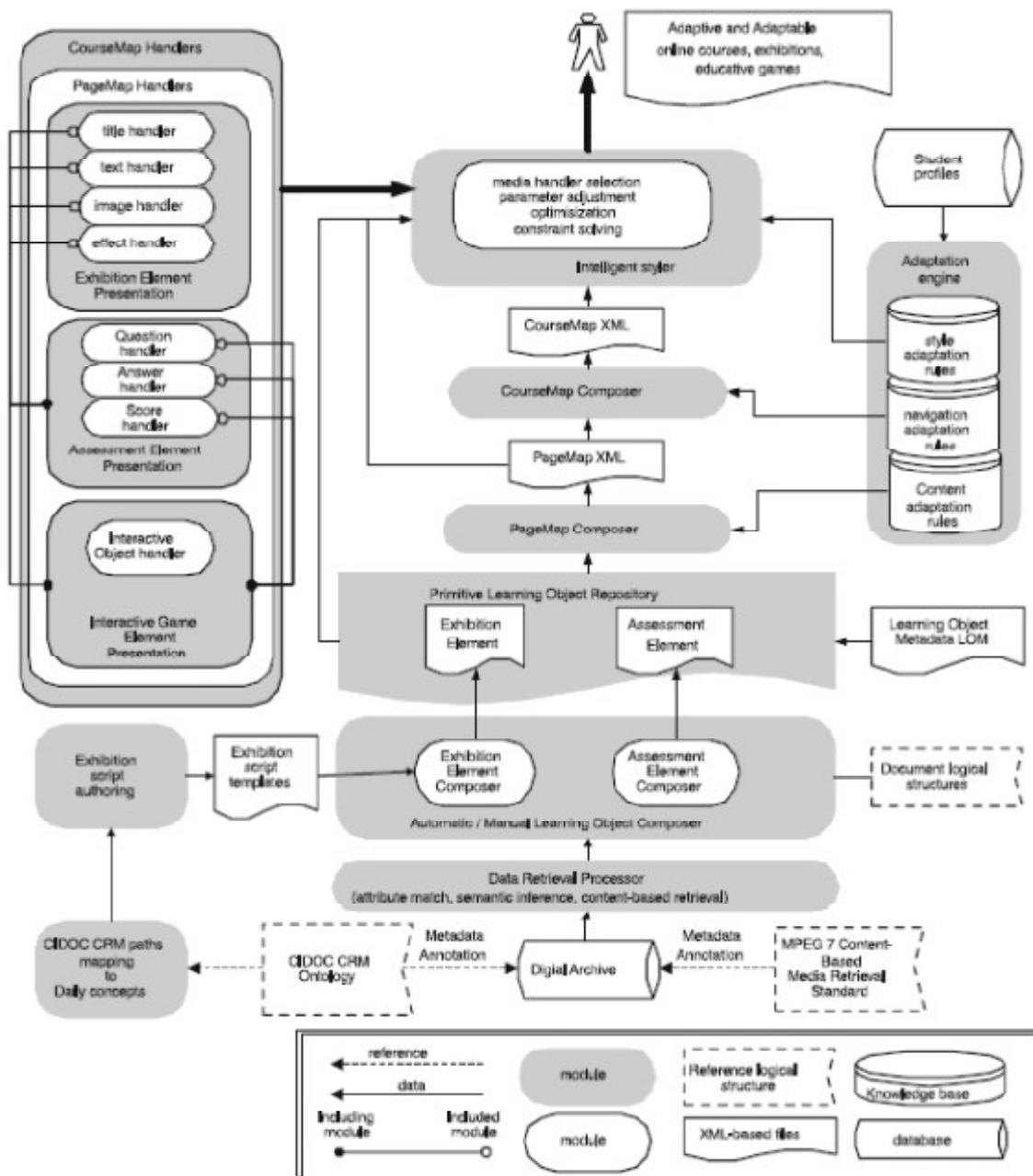
Figure 5. Proposed frameworks for an integrated digital museum system[14].

learning activities. These primitive learning and information objects can be combined to form larger learning entities through the Learning Management System (LMS) or eLearning authoring system (which can either be stand-alone or an integral part of the LMS) to generate stand-alone learning objects which in turn can be aggregated to form larger learning modules. These variations of learning content can be incorporated into VEs as necessary.

Each primitive information object is defined by a set of appropriate metadata (see previous section) which is created, updated and maintained through a DMS. If necessary, a Metadata Management System (MMS) can be used to provide an interface to the DMS to support various metadata operations. This system is not confined to managing primitive information objects: it can also be used to manage metadata for the exhibition, presentation templates and other metadata which the system uses.

The exhibition authoring system forms the crux of VEs authoring. The VE exhibition team uses the system to define the exhibition framework, select information objects (including learning objects if these are present in the VE) for page contents, and create
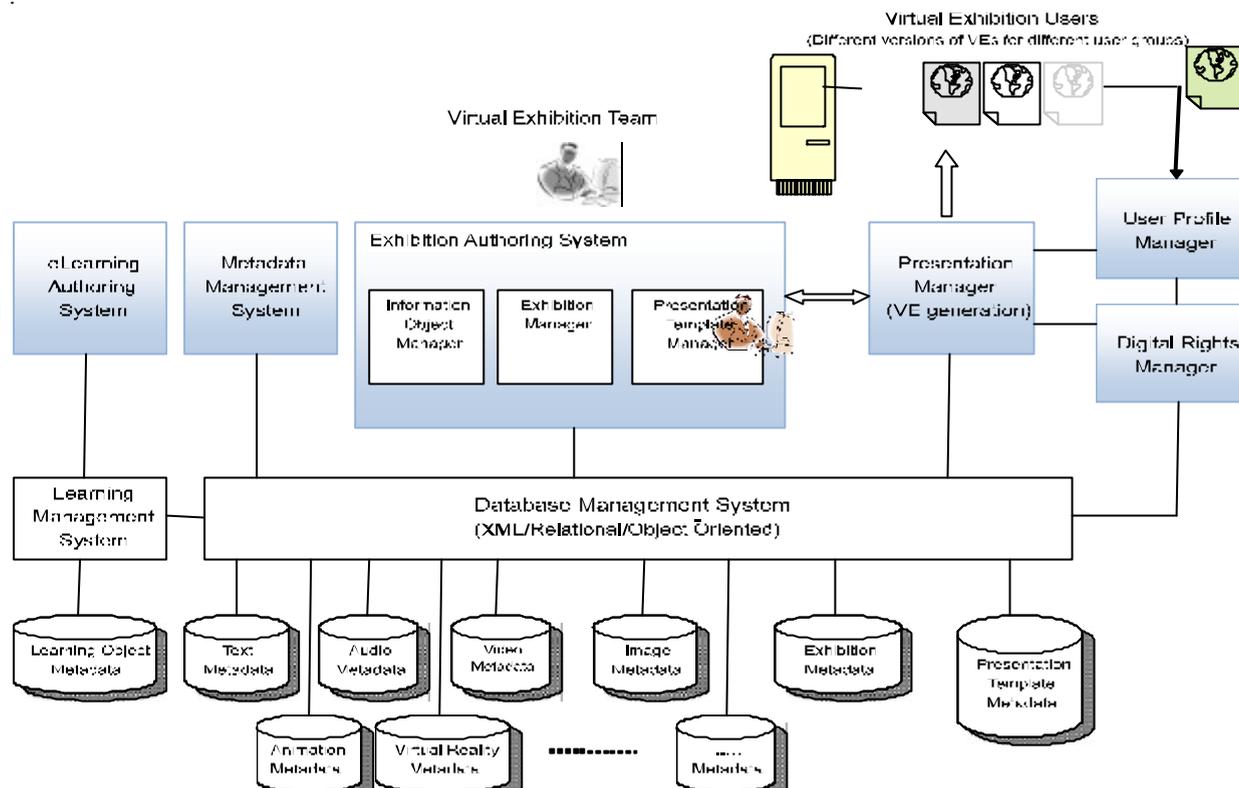
Figure 6. Generic system architecture for VE development.

the layout and look-and-feel of the exhibition pages. This functionality can be integrated as one system, or split into different modules for exhibition page definition, page element selection and presentation definition. This latter approach attempts to clearly separate data from structure and layout. Using an Information Object Manager, exhibition pages can incorporate background music or background image, use a specific layer of information, select different layout setting, font setting during the authoring stage. Different presentations are usually achieved through different presentation or style templates selected during this authoring stage.

These templates can be predefined for selection, or created and managed by a more sophisticated presentation template manager. The Exhibition Manager defines and manages the whole exhibition and combines these various pages together to form the exhibition whose metadata can be stored in the exhibition repository for future reference, editing or updates. The internally generated VE definition can be stored in a suitable data exchange format that is used by the Presentation Manager, whose role is to render and generate the VE into its final form for use by users.

Depending on the way the Exhibition Authoring System is designed, all the necessary information can be made available for the Presentation Manager to complete the work so that VEs can be generated offline. Alternatively, VEs can be generated on-the-fly to take into account client system characteristics and end-users characteristics or preferences. As such, the Presentation Manager may be interfaced with a User Profile Manager to manage these aspects of system and user requirements. System requirements would typically consider client computer processing capability, network bandwidth, and so on, in order for the content to be adapted as necessary. For example, different resolution image, sound and video may be used as necessary to attain an acceptable quality of service for the VEs with different constraints; and resource intensive 3-D graphics may be eliminated if they cannot be adequately supported by the client computer. User characteristics would typically consider age, literacy level, motive for using VE, kind of experience desired, and so on in order for the VE to be adapted as necessary. As such, the User Profile Manager may require some form of interaction and inputs from the user to complete the information necessary for the VEs to be generated.

Another component that might be interfaced to the Presentation Manager might be a Digital Rights Manager to support a Digital Rights Management System in the case where VEs are loaned out to other institutions and where constraints are placed

on the information objects' use. Such a system may allow other VEs from other institutions to have access to the primitive information objects as content for these VEs. Such an attempt to either provide free or fee-paying access can help promote reusability and sharing, and potentially enhance the quality of the final VEs.

Through the Presentation Manager and these other interfaces, a stand-alone single or many different versions of the same exhibition may be generated at one pass. Ultimately, the aim is to generate different versions of VEs to meet the needs of different user groups, and to user technology to support VE authoring efficiently and effectively, thereby minimising human effort and intervention.

In terms of implementation, a number of common data types, standards and techniques have been utilised in most systems for VEs as shown in Table 1. The table also shows the desirable contents, characteristics and features that have been suggested in literature for successful VEs.

Finally, it is worth note two interesting researches and work-in-progress in the development in VEs. Lu, *et al.*[15] proposed a resource-driven content adoption approach to augment content with metadata in order to display or render content based on available resources. By considering display resolution, bandwidth, processing speed, quality of service and energy, content adaptation may add or remove information based on available resources. Metadata in this case not only contains multi-level content description but also important information and geometric information for computer generated images and animation. As such, their proposed approach does not necessary only use pixel manipulation to change resolution, but aim to represent the information object differently if necessary but yet allow the user to perceive the original intended content. Hong, *et al.*[13] proposed using self-contained fine-grained style modules that can be selected and combined together into a styling system to support creation of different versions of VEs using the same content. It aims to make the work of shaping presentation styles easier and to support the creation of VEs without technology specialists.

6. CONCLUSION

Well designed virtual exhibitions are important extensions to physical exhibitions, providing discovery, learning and other opportunities beyond what the physical exhibitions can offer. Users can be captivated, engaged and even contribute towards the continual update of the exhibition. This paper has presented the case for VEs, surfaced the myriad of stakeholders of VEs, and demonstrated the need for good metadata. Using generic system architecture, the various components and salient points of VE system design and development are highlighted. A list of desirable VE contents and features are articulated. The continuing developments of Web 2.0, VE research, wireless and other technological advances are likely to change the form and capability of future VEs. Nonetheless, virtual exhibitions can, and are expected to, survive and grow as they stand to yield a rich set of both tangible and intangible for institutions that fully embrace the idea of both the physical and virtual operating environment in this Internet age.

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About the Author

Schubert Foo is Professor and Associate Dean, College of Humanities, Arts and Social Sciences, Nanyang Technological University, Singapore. He received his BSc (Hons), MBA and PhD from the University of Strathclyde, UK. He is a Chartered Engineer, Chartered IT Professional, Fellow of the Institution of Mechanical Engineers and Fellow of the British Computer Society. He is also a board member of the National Library Board, and an Advisor of the National Archives of Singapore Board. He has published more than 170 publications in the areas of multimedia technology, Internet technology, multilingual information retrieval, digital libraries and knowledge management. He is a member of the Editorial Advisory Board of the *Journal of Information Science, Journal of Information and Knowledge Management,* and *International Yearbook of Library* and *Information Management*, among others. He has co-authored a book Knowledge Management: Tools and Techniques with Ravi Sharma and Alton Chua, and co-edited a book Social Information Retrieval Systems: Emerging Technologies and Applications for Searching the Web Effectively with Dion Goh in 2007.