Media Matrix: Creating Secondary Repositories

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Abstract. This paper argues for the necessity of digital libraries to increase access to their holdings and have greater impact on e-learning and education by facilitating the creation of secondary repositories. These repositories will provide discipline/community specific metadata and applications and will allow users to find, use, manipulate and analyze digital objects more easily. To this end, MATRIX has developed Media Matrix 1.0 - an online, easy to use server-side suite of tools that allows users to locate specific media and streaming media files found in digital repositories and segment, annotate and organize this media online. This application provides users with an environment both to work with and personalize digital media, and also to share and discuss their findings with a community of users. Through creating a secondary repository of usage statistics and user-generated materials/metadata to supplement both traditional cataloging records and discipline-specific online indexes, tools like Media Matrix can help extend the usefulness of digital libraries without increasing costs to the libraries

1 Introduction

For the purposes of preservation and increased use of their holdings, libraries, archives and cultural organizations have been researching and developing best practices for digitizing their analog collections. These efforts have given users unprecedented access to information. Scholars have long realized, however, that "access" to information must mean more than the ability for a user to link to computer networks. Underlying the meaning of access in relation to digital equity and universal service is the need for a community of users to have the ability to retrieve information "in some form in which it can be read, viewed, or otherwise employed constructively" [2][4][5]. Access thus implies four related conditions that go beyond the ability to link to a network: **equity**, the ability of "every citizen" and not simply technical specialists to use the resources; **usability**, the ability of users to easily locate, retrieve, use, and navigate resources; **context**, the conveyance of meaning from stored information to users, so that it makes sense to them; and **interactivity**, the capacity for users to be both consumers and producers of information. While access to online resources has steadily improved in the last decade, online archives and digital libraries still remain difficult to use, particularly for students and novice users [1].

While access to digital resources has had positive affects on both scholarly research and teaching and learning at all levels of instruction, digital libraries must take the next step and redefine access in ways that help users to **use** digital objects. To this

end, MATRIX has developed Media Matrix 1.0 - an online, easy to use server side suite of tools that allows users to find, segment, annotate, organize, and publish digital media found on the Internet and in digital repositories. This application provides users with an environment not only to work with and personalize digital media, but to share and discuss their findings with a community of users. Because Media Matrix stores a significant amount of information about the digital objects selected by users and user generated annotations per digital object, it both provides a corpus of data on how digital repositories are being used and creates materials that augment traditional cataloguing records. In so doing, it forms a secondary repository that holds metadata generated by its users, additional resources for its users, specialized searches and galleries, extended materials, and pointers to digital objects in primary repositories. Thus the value of the application is that it can enhance the usability, access, and interactivity of digital libraries by facilitating the creation of secondary repositories on top of their collections without significantly increasing costs and time needed to prepare and maintain additional resources. Digital libraries can also utilize, if desired, usage statistics and user generated materials/metadata to supplement traditional cataloging records and applications.

1.1 Spoken Words, Digital Libraries and Users

Even though access to digital objects has grown at an exponential rate, tangible factors have prevented users from fully taking advantage of these resources. We have a long history of working with texts and are comfortable moving through texts, making annotations, summaries, and quotations. Beyond a host of traditional methods, we have at our disposal sets of tools, both freeware and commercial, which help us to cite, catalogue, and annotate texts (*e.g.*, Endnote, Procite, Biblioscape). Streaming media, however, is another matter. Scholars and students, beyond some specialized areas, rarely have worked in the past with media and have often preferred the transcript over the original. While contemporary bibliographic tools have expanded to allow users to catalogue and keep notes about media, they do not allow users to mark specific passages and moments in multimedia, segment it, and return to specific places at a later time. While several initiatives and products (e.g., Annotea, SHOE Knowledge Annotator, NetSnippets) allow users to point to specific online materials or portions of online materials and add their annotations to those pointers, it does not allow users to work with the non-textual, digital media present on those pages. Multimedia thus remains underutilized in education because the tools to manipulate the various formats often "frustrate would be users" and take too much cognitive effort and time to learn [3].

Over the past decade, the digital library community has tried to reduce the labor and expense of creating, cataloging, storing, and disseminating digital objects through the research and development of specific practices to facilitate each of these stages. Although these processes have become easier, better documented, and more automated, creating and working with digital objects is still a very specialized endeavor that requires specialized hardware, software and expertise—often outside the realm and resources of the general user. Even with the resources to work with digital media,

copyright restrictions and streaming technologies make it difficult for users to download, manipulate, and use digital objects in their own practices.

To compound this, traditional cataloging and dissemination practices often make it difficult for users to locate and utilize digital objects within the framework and practices of their discipline [10]. Digital objects are typically cataloged to describe their content (bibliographic information), composition (technical metadata), maintenance (administrative metadata) and dissemination (rights metadata and any information for delivering the object via online applications). While these practices are essential for preserving the digital object and making it available to users, the practices also make it available to users in a language and guise that is often difficult to understand within the context of use [10].

While the author's name, the title of the work, and keywords are essential for describing and locating a digital object, this kind of information is not always the most utilized information when users are looking for and ascertaining the relevance of a digital object. K – 12 teachers, for instance, often do not have specific authors or titles in mind when searching for materials for their classes. They more frequently search in terms of grade level, the state and national standards that form the basis of their teaching, or broad, overarching topics (*e.g.*, core democratic values or textbook topics) that tend to retrieve too many search returns to make the information of value. Although the addition of more discipline specific information at the object level would open up the digital libraries to larger constituency and enhance the impact and usability of digital libraries, it would be a huge and unrealistic endeavor for digital libraries given the multitude of disciplines that would benefit from the addition of discipline specific information attached to each object.

The keys to making better use of multimedia in education and to enhancing the use of multimedia for specific contexts and disciplines, are to build secondary repositories with resources and tools that allow users to enhance and augment materials [11], share their work with a community of users [14], and easily manipulate the media with simple and intuitive tools (or at least build interfaces that match existing, well-known and heavily-used applications). Users will also need portal spaces that escape the genre of links gateways and become flexible work environments that allow users to become interactive producers [8]. In short, secondary repositories are the result of users integrating digital objects into their research and work in ways that make sense to them given their backgrounds and tasks.

Herbert Van de Sompel has proposed a successful system (OpenURL/SFX framework for context sensitive reference linking) for disaggregating reference linking services from e-publishing [15]. In his framework, the service of providing links between references and across e-publishers' digital repositories is separated from the services provided by the e-publishers. In so doing, the service provides "seamless interconnectivity between ever-increasing collection of heterogeneous resources," freeing primary repositories from the difficult and expensive task of ensuring links to references while giving users greater access to resources and increasing the value of the digital object [16]. Similarly, we propose the creation of secondary repositories that would be responsible for handling secondary metadata, extended materials and resources, and interactive tools and application services. Generated by interactive, online tools, these resources would work to contexutalize, add meaning, and provide new ways of discovering the original digital object. Primary repositories would con-

tinue to be responsible for preservation, management, and long-term access but would be freed from creating time-consuming and expensive materials, resources, services, and extended metadata for particular user groups.

2 Media Matrix

MATRIX - The Center for Humane Arts, Letters, and Social Sciences Online is a humanities computing research center based at Michigan State University. Over the last five years, MATRIX has participated in the ongoing discussion and development of digital library practices and has built a large-scale digital repository. This digital repository holds over fifteen collections that contain a diverse range of materials from different disciplines – from images of quilts to nineteenth-century renderings of tumors, to recordings of indigenous practices of West African tribes-people, to the interviews of the oral historian, Studs Terkel. The variety of these materials has drawn a diverse crowd of users who come to the sites from different disciplines and with vastly different agendas. MATRIX's research agenda—initially under a five-year National Science Foundation Digital Libraries II grant (1998) to develop a National Gallery of the Spoken Word—has focused on how best to build the infrastructure of a spoken word repository and the best practices for digitizing and disseminating the objects within repositories. While this research has been very successful and rewarding, the focus of MATRIX's research agenda has shifted—under the Spoken Word Project funded by Digital Libraries Initiative II: Digital Libraries in the Classroom Program, National Science Foundation in conjunction with UK's Joint Information Systems Committee—in part, toward how to best make digital objects useful to digital library users, especially for education and e-learning.

The Spoken Word project focuses on helping to transform undergraduate learning and teaching through integrating the media resources of digital repositories into undergraduate courses in history, political science and cognate disciplines in the U.S. and Britain. The project takes advantage of the flexibility inherent in digital repositories to build processes for learning that will expand how students and teachers understand knowledge, knowledge resources, and their own complementary roles in higher education. The project is a collaboration of Michigan State University, Northwestern University, the National Archives and Records Administration (NARA), Glasgow Caledonian University, and the BBC - Information & Archives. Project researchers are testing whether and with what effect the integration of digital audio resources into university courses achieves four major project outcomes: (1) improving student learning and retention, (2) developing aural literacy in our students, (3) augmenting student competence to write on—and for—the Internet, and, (4) enhancing digital libraries through a focus on learning.

Research on these areas has led to the development of an application called Media Matrix (version 1.0)– an online, server side tool that helps users to find, segment, annotate, organize, and publish streaming media found on the Internet.

2.1 Media Matrix Tool Set and Operation

A user begins using Media Matrix 1.0 by registering for a user account at the Media Matrix web site. In the process, users complete a short profile that describes generally their teaching and scholarly backgrounds. Users are then issued an account that gives them access to the Media Matrix tools and a personal portal page for gathering, organizing, and publishing the materials they create and gather. Users are also given the ability to create groups to which they can invite other users to join. The group function is a key element of the tool set because it allows users to share resources and collaborate on the development of resources and projects with other members of the group. Teachers can thus create a group for each of their classes and invite students to join that group. This allows both the teacher and students to preview the work of and collaborate with other members of the class easily.

Fig. 1. Media Matrix user portal page.

Media Matrix does not require any special downloads or plug-ins, a feature that makes the tool more accessible to teachers, students and researchers, who may be working in computer labs and at library work stations that often do not easily allow for the downloading of additional software. Focusing on maintaining a familiar work environment, Media Matrix works within the browser of the user, and works with the same media players normally used to play digital objects. Users continue to use Media Matrix by dragging five links (favlets) provided on their portal page to the bookmark bar of their browser (see Figure 1). Users can then search for objects on the internet using their own methods and preferred tools or go directly to sites where they want to work with digital media. When users find a digital object that they would like to use or work with, they simply click the appropriate link and Media Matrix is

launched. In the case of audio, the user would, for instance, find an audio clip on any site on the internet (e.g., American Memory, CNN, BBC, or ESPN). They would then press the "Find Audio" link saved on their bookmark bar. Media Matrix then uses regular expressions and string matching to isolate any audio files referenced on the page and loads the sound into the editor. If multiple sounds are on the page, Media Matrix has been designed to allow users to preview and select the sound they want to load into the editor. Because there are virtually any number of ways a digital object can be embedded and described on a web page,

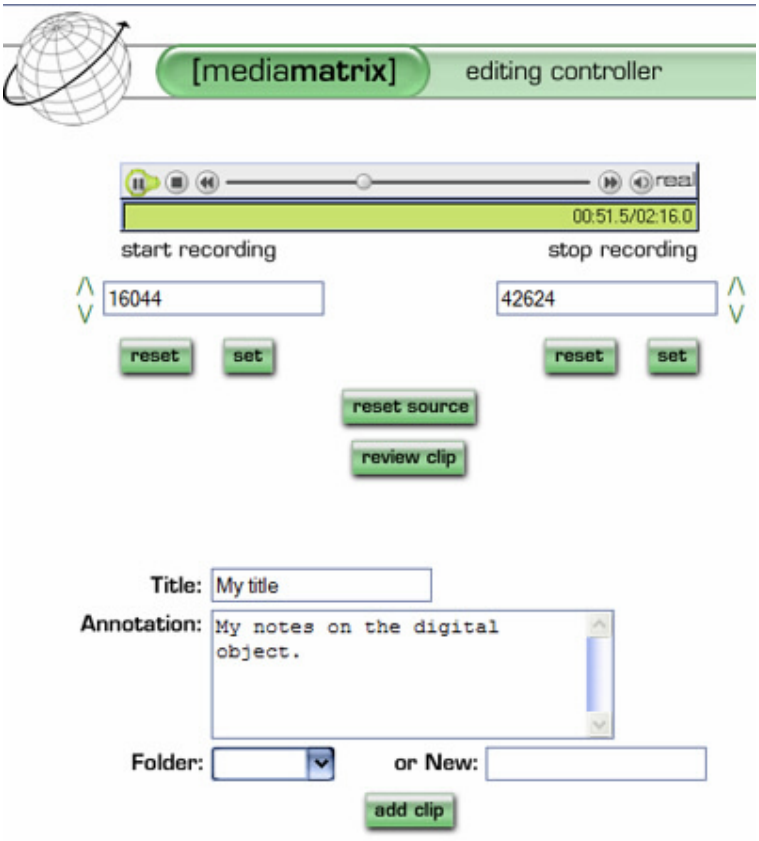

Fig. 2. Media Matrix segmenting in online editing controller window.

Media Matrix can only reliably identify the URIs of media found on a specific web page. The streaming media is then loaded into the appropriate media player (Real Player, QuickTime, Windows Media) and embedded into the Media Matrix online editor (see figure 2). Taking advantage of existing resources on users' computers and working with formats supplied by repositories, Media Matrix allows users to employ common players to control the playback of the audio. While the audio is playing,

Media Matrix permits users to "record" portions of the streamed clip. When the user finds a portion he/she believes is important, he/she simply clicks the "Start Recording" button and then the "End Recording" button to capture a segment of the sound. Media Matrix does not actually record the audio, but instead stores the URI of the clip and the time offsets for that portion of the clip selected by the user. When the user replays the clip those offsets and the URI of the clip are then passed back to the player and thus only the selected portion of the streamed audio is replayed.

After segmenting the sound file and isolating the portion(s) of the streaming clip users want, users can then add their own thoughts or analysis to the clip in the form of annotations. The user then titles the clip/annotation and submits it to his/her personal portal page. The annotations can then be easily saved, accessed, combined, exported organized, edited, shared, and published.

Using the same basic steps, Media Matrix works with other media types. Users can work with video in much the same way as audio, allowing students and researchers to isolate portions of the video and add an annotation to the sections of the clip that they have selected. Media Matrix also allows users to bookmark whole web pages or pages of text or copy portions of the text into their portal as well as describe that text through the use of a title, annotation, and keywords. Similarly images can be cropped and resized by the user as well as annotated. This can be particularly effective for students and researchers who need to fit images into a presentation or would like to demonstrate specific nuances and details about portions of images or artwork.

In the case of each media type, Media Matrix works much like standard note-taking and bibliographic tools but gives users greater control over manipulating the media and maintains users' work in an online (and optionally collaborative environment). Once users find, segment, and annotate streaming media, they can then organize those entries on their personal portal page. The portal page allows users to create trees of meaning and organization through the use of nested folders. Users have the ability to display the contents of each of their folders to particular groups they have joined, to the general public by removing any access restrictions, or maintain the resources for personal use only. Once they have organized the media that they have collected, they can integrate that media into multimedia publications.

2.2 Media Matrix Delivery Presentation Layer

Users can choose from a number of presentation templates that allow them to select digital objects from their portal page (audio and video segments, images and image selections, text, and annotations) add text and analysis, and submit for publication. This creates a web page presentation with a persistent URI that features the writing of the user and the digital clips he/she has selected. This is an especially important feature requested by instructors because it allows teachers and students both to make presentations in the classroom and to create multi-media essays for submission.

The suite of tools developed for Media Matrix not only allows users to work with and analyze digital objects, but also affords users the ability to locate new digital objects. Media Matrix uses the information users submit when creating their profiles and groups to create browse-able and searchable access points to portal pages created by other users. Historians, for example, can browse the portals of other historians

working specifically in their research areas or K-12 teachers can browse grade appropriate sections defined by specific grade levels and subjects to see what digital objects other teachers are using or, more important, for time challenged teachers, they can find specific presentations created around standard topics and curriculum frameworks.

Users can also perform keyword searches over the annotations created by all users or specific groups of users. A teacher, for instance, can choose to search through only the information in eleventh-grade Civics groups in hopes of finding information that speaks directly to his/her needs. Because users have gathered content from across the Internet and from a variety of digital repositories, searching Media Matrix is equivalent to searching multiple repositories at once. Once users find an object from a particular digital library, they can jump to that repository to find what other objects are available.

2.3 Media Matrix and Metadata Augmentation

One way to alleviate the high costs of augmenting metadata is to create a distributed model of augmentation. Not unlike the model for the development of open source software, digital libraries can rely on communities of users to develop the accessibility and usability of their collections in a secondary repository. Along these lines, Media Matrix allows users to create rich sets of discipline specific user generated metadata. The segments, presentations, and annotations created for each digital object can serve to augment the original finding aid for the digital object. It also supplies information not only about the popularity and relevancy of specific resources, but also about most used segments and the content of files.

Collections can also benefit by defining communities of users. For example, with the recent release of secret White House tapes [7], the sheer number of tapes and hours make it impossible for adequate cataloging of content as well as the difficulty of determining the context and people involved (or even what is said given the poor quality of many tapes). Those historians and scholars (a more regulated and highly defined set of experts) allowed access to the collections could use Media Matrix to supply information about content and context as well as set terms for debates over more questionable areas of interpretation (e.g., when sound quality makes passages inaudible). While metadata gathered in these ways would need to be qualified (maintained in a secondary repository) because of lack of quality control, the processes could make large quantities of sound more available and usable (as well as searchable since annotations will be keyed to particular time offsets).

Because users can search directly using the Media Matrix environment, MATRIX also plans to give any digital library and online sound collection open access to its logs (those logs that apply to the specific collection). A digital library can export from Media Matrix any usage statistics and information about the specific digital objects users are accessing in their collections. This information can provide digital libraries with information, i.e., who is accessing their holdings, which objects are being accessed and in what portions of those objects are users most interested. MATRIX is planning on using this information to build for users dynamic recommendation lists based on other users' preferences (e.g., Amazon). In doing so, we can search Media Matrix and find users who have annotated specific objects and then suggest other

segments and objects in that content folder of their portal page, a service that would greatly enhance the usability while helping to augment context for digital objects.

2.4 Media Matrix Programming Environment

Media Matrix is a PHP based server side application that stores information in a MYSQL database and exports that information into XML for display. The development of the tool and programming environment have been designed to keep it library and archive independent so that it can work with almost any site on the internet. It can also work easily with any of the standard courseware packages. The tool is also search independent because it relies on traditional internet search tools and a site's discovery tools to find an object. Once objects are found, Media Matrix is deployed by the user. Because Media Matrix does not actually copy the digital object from the site (it only stores a pointer to the object in the form of a URI and whatever time offsets are created by the user), it avoids some of the copyright and fair use pitfalls that often keep users from working with digital objects (although there are issues of deep linking to be addressed).

The continued development of Media Matrix faces several challenges. Media players and browsers are central to the development of the application. Media Matrix, as noted, uses both browsers as its native environment and media players to stream media because users are comfortable with these environments and it does not necessitate further software installation. The most popular media players—Real Player, QuickTime, and Windows Media Player—all have API's that allow information to be passed between the player and the browser. Because of this, clip information such as time parameters can be grabbed from the player to record time offsets or passed back to the player to play only the portion of a clip. The most common method of doing this is with JavaScript. Although this is an adequate development platform given some OS environments and browsers, it is highly problematic in others.

Players have a troubled history of playing clips formatted for other players (although several claim to allow trouble-free playing of a number of formats). Real Audio does not play QuickTime files, for instance. Because of this, code must be written to identify and interpret the kinds of files that are being edited by Media Matrix and then separate code must be written for each player to pass information back and forth to the browser. Although JavaScript is a popular, standardized scripting language, not all browsers interpret it in the same manner, particularly event functions. Because of this, the full functionality of Media Matrix remains limited to Internet Explorer 6.0 and PCs. It remains functional in Netscape and other browser environments but currently has limited functionality on Mac OS X. Further research and development should allow us to expand its use and functionality in terms of players, browsers and platforms. MATRIX has considered employing Macromedia's Flash as an environment for Media Matrix and will continue to do so, but Flash also has limitations in working with particular players and browsers, especially Real Audio in its native environment.

2.5 Media Matrix Beta Testing

Steve Cohen of Tufts University completed an initial assessment of using digital libraries and Media Matrix in a classroom setting. For the assessment, a survey history course of 150 students at Michigan State University, History 203, which covered twentieth-century American history, was chosen. A sample of 40 students in three different sections of the course was given written surveys to complete and of these, 10 students were interviewed in more detail. No controls or quasi experimental protocols were used, so results can only be considered as trends and will be used to design more comprehensive assessments for the Fall Semester of 2004 and to do initial usability revisions of Media Matrix.

In sum, students were positive about their experience with both digital libraries and Media Matrix. Most students visited between 2 and 5 digital libraries to review and acquire sources for their essay assignment and spent totals of 4-8 hours on task (low=2, high=20). Most reported that, based on their experience in History 203, they would be more motivated to enroll in a course that used digital libraries and Media Matrix, and. most reported that the images and audio helped to improve their work, the material "came alive."

2.5.1 Digital Libraries Usability. Overall students would like more digital library resources given to them that work for the assignment and work with Media Matrix. They would like the search capabilities of digital libraries improved with more advanced features, annotations, thumbnails, topic searches, and easier access. Often students were not clear about what they meant by easier access and better navigation and searches, but they found digital libraries hard to use because it was difficult for them to sort through the resources or find resources that fit their topics. Often they noted that they would like materials to be better annotated and organized by topics. As Cohen noted, the problems with digital library interfaces were "not an issue of technical skill but rather design and informatics. During the group interview students suggested that the DLs did not have good interfaces for browsing, but seemed to be designed for users who already knew what they were looking for."

2.5.2 Media Matrix. The suggestions for Media Matrix fell into three main categories:

1) Improved instructions: the instructions need to be written for those not familiar with technology, step by step, and placed at point of need.

2) Improved presentation layer: students would like to be able to have more format controls over text ("to work like a word processor") and do in-text citations; they wanted to create a more professional looking essay.

3) Easier to use: what was meant by easier to use was more difficult to define but for the most part, students wanted Media Matrix to work with more kinds of file formats, digital library sites, and operating systems; and they wanted more information on the pop-up window that listed resources found on a web page (if more than one source was found on the page) to identify the resource.

Other significant comments focused on creating a FAQ; starting with a smaller assignment (students were asked to write a 2500 word essay using text, images, and sound) or shorter sequenced assignments; students would also like to add resources to their resource tree without leaving the presentation layer.

Based on the surveys and interviews, in addition to improving the usability of digital libraries and Media Matrix, Cohen has initially concluded that students need more help with understanding the value and use of sources that they do find. One way we will attempt to do this will be to increase the number of fields that students will be required to complete for an annotation, allowing students, for example, to note who, when, where and the motives of the creator(s)/participant(s). Students should also be given space and prompts to evaluate the source and its context. These and several of the other above suggested improvements are being incorporated into the tool set.

3 Conclusions

Digitizing collections and putting them online provides new and unprecedented access to information, but to have an impact on e-learning and education, it is no longer enough for digital libraries to stop at search and browse. Digital libraries must take the next step and help users employ those digital objects in ways that make sense to specific user communities and academic disciplines. Whether it is the addition of GIS information and the creation of GIS aware applications that let historians view objects in time and space, or search interfaces that take into account the pedagogical environment of educators and help them find resources to utilize within specific assignments, or applications that bring content alive for students through 3D rendering and role play, digital libraries must work closely with users to discover the unique perspectives they bring to the site and build applications that bring digital object alive within those worlds.

Given the present budget crises and the costs and time associated with digitizing materials and managing digital repositories, it is often not feasible for digital libraries to offer extended services. Creating secondary repositories that can make use of a number of collections and focus on the needs of particular user groups (especially for e-learning) makes more sense for users and digital librarians. Correctly deployed secondary repositories, created from user generated data with specific applications, can increase visibility and accessibility of existing collections and thereby help digital libraries and archives to cultivate the full meaning of access: equity, usability, context, and interactivity.

Although development of applications to work with more browsers and players is necessary, Media Matrix 1.0 has proven highly successful in its first run. It has been a marriage that has proven fruitful for both users and digital libraries. Users have a way to utilize and personalize digital objects and digital libraries have access to a wealth of information that can be tied to the digital object. Creating Media Matrix has helped us to redefine the term access and to imagine a more flexible and interactive work space for scholars and students. This is particularly crucial when it comes to sound archives: if we do not enhance the value of sound for users and increase the demand, then our sound archives will continue to languish in neglect and decay.

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