Extending the Role of Metadata in a Digital Library System*

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Abstract

We describe an approach to the development of a digital library system that is founded on a number of basic principles. In particular, we discuss the critical role of metadata in all aspects of the system design. We begin by describing how the notion of metadata is sometimes interpreted and go on to discuss some of our early experiences in a digital conversion project. We report on the Profiles in Science project, which is making the archival collections of prominent biomedical scientists available on the World Wide Web. We discuss the principles that are used in our system design, illustrating these throughout the discussion. Our approach has involved interpreting metadata in its broadest sense. We capture data about the items in our digital collection for a a variety of purposes and use those data to drive the entire system. Futher, we have designed our overall system architecture such that it can accommodate changes while still ensuring the persistence of the underlying data.

1. Introduction

Metadata in its broadest interpretation is data about data. The importance of metadata as an aid to resource discovery is acknowledged in the digital library community. The Dublin Core initiative is a metadata standardization effort whose goal it is "to define a core set of elements for resource discovery" [1], and, in particular, to develop a set that "provides adequate data for Web resource discovery and is simple for authors and content managers to create and maintain" [2:176]. Thiele in a recent review article says of the Dublin Core: "The object is to develop a simple metadata set and associated syntax that will be used by information producers and providers to describe their networked resources, thereby improving their chance of discovery." [3].

Metadata interoperability is a closely related issue and is also a focus of current metadata research. Daniel, in discussing the Warwick Framework, says:

> *Metadata efforts often fall into the trap of trying to create a universal metadata schema. Such efforts fail to recognize the basic nature of metadata: namely, that it is far too diverse to fit into one useful taxonomy...the creation, administration, and enhancement of individual metadata forms should be left to the relevant communities of expertise. Ideally this would occur within a framework that will support interoperability across data and domains.* [4:277]

Roszkowski and Lukas describe an approach for linking distributed collections of metadata so that they are searchable as a single collection [5], and Baldonado et al. describe an architecture that facilitates metadata compatibility and interoperability [6]. Current developments in metadata standardization, including interoperability issues, are reported regularly on the Web [7-9].

2. Lessons learned from an early digital library project

Some years ago, as an experiment in document management and conversion, we developed a digital library system of historical materials. Though our work on this system, which we began in 1992, pre-dated recent research in digital libraries, we encountered many of the same issues that currently face digital library projects, particularly those that are involved in converting large collections of materials from paper to digital form. Often projects of this type bring together two worlds, the rich world of archival practice and the world of emerging technologies. While archivists generally operate at the level of an entire collection, digital conversion projects require careful attention to individual pages and documents. This has major implications for the way in which a collection is processed. Archivists traditionally sort, organize, and catalogue a collection, producing as a final product a finding aid. The finding aid imposes a structure on the collection and indicates, generally at the folder and box level, where the physical documents may

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be found. In digital conversion projects primary attention is paid to the identification and management of documents, with perhaps somewhat less attention being paid to the overall structure of the collection. The physical location of the documents becomes of secondary concern (in some cases, the physical documents are even destroyed), and of primary concern is the ability to locate the documents in a database or over a network. If the optical character recognition (OCR) is successful, then retrieval by key words can be somewhat effective. However, if, as is often the case with older materials, the OCR is inadequate, and if the item being converted is a photograph or some other non-textual item, then some other method is needed, in any case, for finding the individual items in the collection.

Our early project involved historical materials from the Regional Medical Programs (RMPs) initiative whose goal it was to establish regional centers of excellence for health care throughout the United States involving medical schools, research institutions, and hospitals. The RMP archival materials span the entire history of the project beginning with an initial report to President Johnson in 1964, through the active period of program implementation, and to its termination in 1976. In addition, materials from a conference held at the National Library of Medicine (NLM) in December 1991 are included. The material in the RMP collection presented us with a variety of challenges, either because the documents were of very poor quality (including mimeographs, and, in some cases, photocopies of mimeographs), or because they were oddly sized (including folded pamphlets, oversized books, loose-leafed binders, pages from memo pads, etc.). In addition to the scanned documents, interview transcripts, audio segments, photographs, and conference session transcripts are included in the database.

We digitized some 1,500 documents, representing about 40,000 pages and developed what is now called metadata for each of the items in the database. The purpose of the metadata, which is made available as an "index" record, was to ensure that documents could be retrieved even if the OCR was inadequate (which it often was). The metadata also served to link the various forms of the same document (e.g., TIFF, OCR, etc.) to each other through the unique identifier that was assigned to each document. Metadata templates, which were used to standardize the information being collected, varied by document type. Thus, for example, published articles would have information about authors, journal, publisher, place of publication, etc., while unpublished letters would include information about the sender and the recipient. Common to all document types would be information about the contributor, number of pages, location of the physical document, scanning and index dates, and index terms from NLM's Medical Subject Headings (MeSH) thesaurus, together with a controlled terminology that was special to the RMP documents.

We scanned the documents, creating a digital master. The master copy is a high quality, lossless TIFF image from which other formats may be derived over time. When the Web technology first became available, we created a Web-based version of the system. Our first challenge was to make the TIFF images available through the Web without requiring users to acquire additional viewing software. We experimented with GIF derivatives of the TIFF pages, but at full size these took an unacceptably long time to download, and at reduced size their quality was unacceptable. When the portable document format (PDF) became available, and, importantly, when the viewer became freely available as a browser plug-in, we derived PDF images from the original TIFF's and then made both versions available on the Web site [10].

3. A new challenge: metadata driven conversion

Founded on our early experience with the RMP program materials, we began a project in the spring of 1997 whose goal it is to make the archival collections of prominent biomedical scientists available on the World Wide Web. The site is designed for scientists, scholars, and students, all of whom may gain an appreciation of the history of early scientific discoveries, and also share in the excitement of the scientific enterprise. The collections have been donated to the NLM and contain published and unpublished materials, including books, journal volumes, pamphlets, diaries, letters, manuscripts, photographs, audio tapes and other audiovisual materials. The site was officially launched in September 1998 [11]. The first collection on the site represents the work of Oswald Theodore Avery (1877 - 1955), one of this country's first molecular biologists, whose findings proved that the genetic material is DNA.

Underlying the *Profiles* Web site is a system that is designed to handle the entire life cycle of a large-scale conversion project. Metadata forms the core of the system. It is the major component of the data input stage; it is used for generating various views for display on the Web; and it serves as the basis for search and retrieval.

The primary principles underlying our system design are modularity, adherence to standards, and extensibility. We create high quality original images and detailed metadata records. From these, we are able to automatically derive a variety of other image formats, and we are able to derive a variety of views for our Web site. We automate whatever it is possible to automate, hoping thereby not only to ensure accuracy, consistency and efficiency, but also to contribute to ease of use. Creating a digital archive is a labor intensive effort, and we are attempting to design a system that minimizes the burden of routine data entry, allowing the archivists to concentrate instead on the intellectual aspects of the tasks at hand.

3.1. Digitizing and loading the repository

Figure 1 illustrates the architecture of the *Profiles in Science* system.

Items chosen for digitization include photographs, electronic documents (documents or photographs that are "born" digitally [12:4]), paper documents, audio recordings, and videos. The archivist uses the customized metadata entry system that we created to enter descriptive and administrative metadata. The descriptive metadata is typically externalized as Dublin Core, and all the metadata is intended to allow mapping to a variety of element sets as needed.

The system provides a number of document management capabilities, including tracking functions. It also has built in quality control features and provides a variety of reports, including an automatically generated scan sheet. These scan sheets accompany the physical objects throughout the digitization process, providing information and instructions for the scanner and feedback to the archivist about problems encountered during the scanning process.

Once the metadata for a set of items has been entered, the process of creating the master digital object begins. High resolution TIFF files are created as the digital master copies from which a variety of Web-accessible derivatives is created. Adobe PDF is derived from the master TIFF files for black and white documents, and 2 sizes of JPEG are derived from the greyscale and color TIFF files. Web-friendly streaming audio and video formats (QuickTime and RealMedia) files are produced from the video and audio files.

When document scanning is complete, the scanning technician deposits the scanned files into an incoming directory, indicating that the items are ready to go through the quality control process. At that point, the scanning technician returns the original items to the archivist.

The metadata entry program reads the incoming directory and performs some basic checking, for example, to see if pages are missing, or if a file is named according to a non-existent unique identifier. Items that pass this check are marked as "ready" and those that do not pass are marked as "incomplete" and are moved to a "redo"

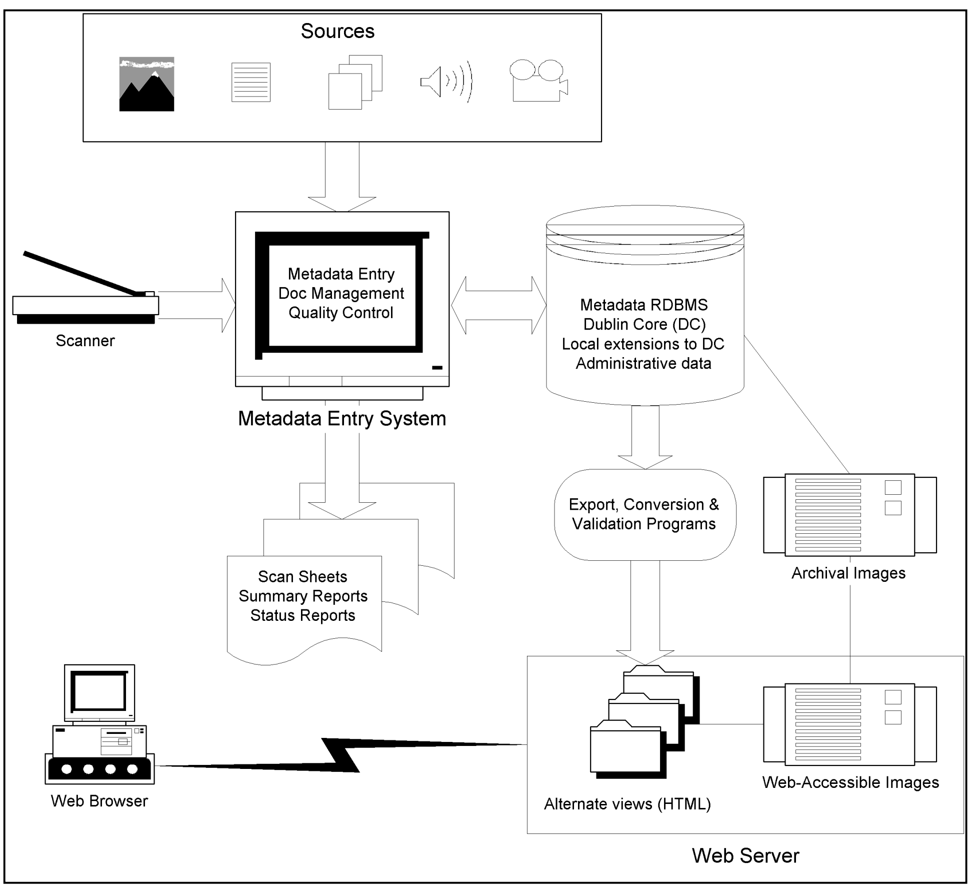

Figure 1. Architecture of *Profiles in Science* System

directory. The archivist checks each original item against the ready items, and uses the metadata entry system to change the status of each metadata record to either "final" (if the item passed quality control) or "redo" (if the item failed quality control). Items that failed either the automated or manual quality control are returned to the scanning technician. Information such as which technician scanned the item, and when the item was moved through each stage of quality control and by whom, is automatically logged by the DBMS.

Those digitized items that pass final quality control are moved to the archival image server or the Web server as appropriate. The DBMS is exported and a suite of programs performs more validity checking, creates HTML pages for the metadata records which point to the Web-accessible derivatives, and creates sets of HTML pages which allow multiple views of the collection.

3.2. Entering and validating metadata

The metadata entry system is used to collect a sufficient amount of data about individual items to allow any item to be found during a search of the collection, and it performs a number of functions in addition to recording descriptive information about the items in the collection. The design of the system encourages correct, consistent, and standard collection of metadata. It allows multiple persons to enter metadata simultaneously, providing a common interface for all persons entering data, and enforcing the notion of required fields. Whenever possible, data are entered by choosing from enumerated lists. Data validation is performed by the system wherever appropriate, and warning messages are generated to alert the user to potential problems.

Since most items require that permission be sought before they can be made available in digital form to the public, capabilities are provided in each metadata record for recording information about the status of copyright permissions, as well as any special restrictions imposed by donors.

The metadata record also allows the archivist to enter information that relates to the intellectual organization of the collection. Thus, the particular series or sub-series into which a document falls can be entered. Our future plans

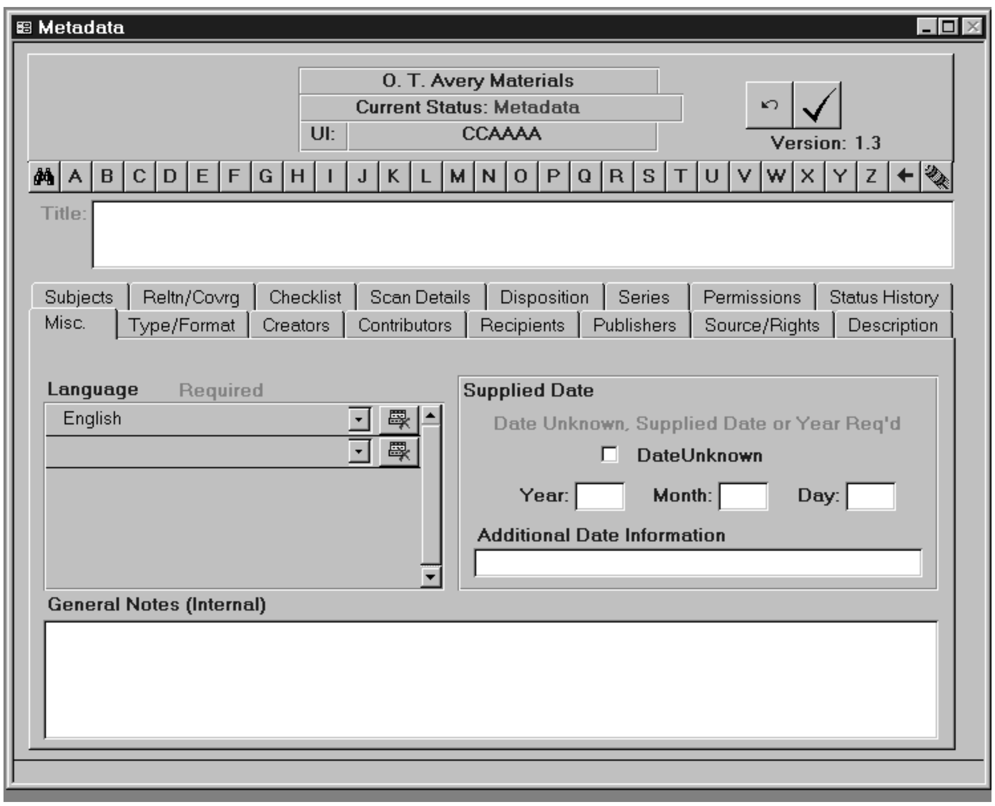

Figure 2. Initial metadata entry screen

are to extend this capability even further by incorporating additional elements found in encoded finding aids [13].

The permanent physical location of an item, such as a box or folder, is also recorded. Special information, such as the location of an item temporarily removed from the collection, can also be documented in the metadata record. Since various types of personnel work on various parts of the process, levels of access to the metadata entry system can be granted to different groups such as scanners, archivists, and supervisors. The access levels may apply to certain fields in a metadata record, or they may apply to entire collections.

Figures 2 - 4 are illustrative screen shots of our metadata entry system. Figure 2 shows the first screen an archivist sees.

As each item is logged into the metadata entry system, it is assigned a unique identifier. When the archivist enters the system, the next available unique identifier for the collection being processed appears. The user would enter the Dublin Core information about the item as appropriate: Title, Subject (keywords), Relation, Coverage, Resource Type, Format, Creator (author), Contributors, Publisher, Source, Rights Management, Description, Language, and Date. These category names correspond to Dublin Core elements because they were close enough for our current purposes and made the mapping to the Dublin Core element set, currently the best available standard, quite easy. The unique identifier that stands in for the Dublin Core resource identifier is assigned by the system. Other types of information includes quality control checks, instructions about disposition of the document after digitization, the physical condition of the document, and where the document fits in the physical and intellectual organization of the collection.

The archivist chooses from drop-down lists when entering data whenever possible. Depending on the type of entry chosen, a window pops up displaying the appropriate elements that would apply to that entry. Figure 3 illustrates.

In Figure 3, the user has chosen "Journal Article" as the source type and would choose the correct Journal name from the authoritative list. Then volume, issue, pages, and ISSN number for the document would be added. These elements are stored separately in the database, but when the choices are made they are displayed in a standard combined form in the Source field. Changing the formula that creates the combined

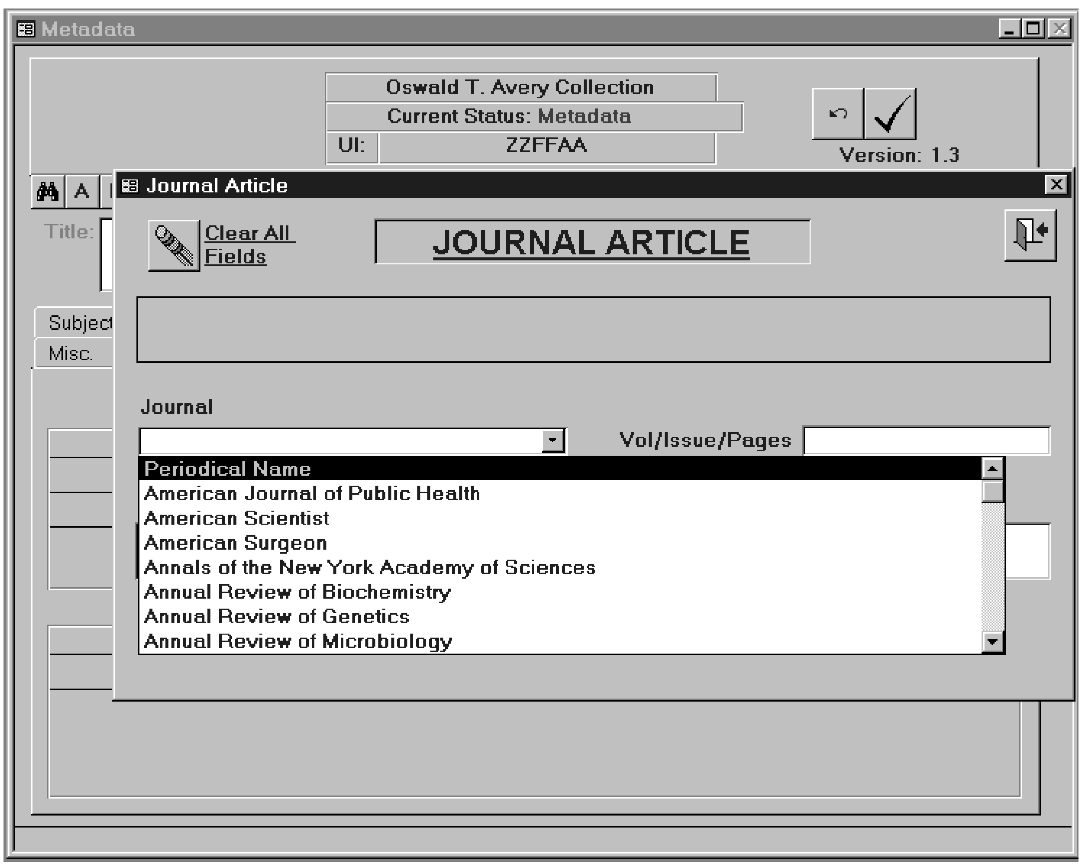

Figure 3. Choosing items from a list

form would require no changes to the data since the elements are stored separately. Consistency is increased, since the combined form is based on a formula instead of free text.

Although Dublin Core specifies that all fields are optional and repeatable, we require that certain elements be entered for each record. This is so that a reasonable amount of minimal information is included for every item entered into the system, and it ensures that the basic information needed to create a view of the collection based on the metadata exists. The archivist may not save the record until the required data are entered (or designated as unknown). Figure 4 illustrates.

4. Roles of the metadata system

4.1. Input: framework for collection management

The metadata entry system manages all aspects of the digitization process. Once the scope and overall arrangement of a collection are determined, and items are chosen for digitization, the archivist begins entering metadata for each item. The unique identifier binds the digital master files and Web-accessible derivatives permanently to the metadata record. Thus, the TIFF, PDF, and OCR versions of a document are all linked by the same unique identifier as is the full metadata record that has been created for that document. In some cases a word-processed form of a document may co-exist with a printed version of that same document. In that case, the same identifier for the digital image of the printed document will also link the word-processed form.

The archivist records information about the physical object, such as its location, including the method of organization, e.g., the folder and box in which the document resides and the series or sub-series of which it is a part. Information about the quality of the physical object is included. If the item is fragile, oversized, or needs special handling of any type, this is recorded in the system (for use in the subsequent scanning stage). Additionally, and importantly, information about the status of copyright permissions is also noted.

The metadata entry system enforces quality control. Pull-down menus, check boxes, and option buttons are used whenever possible, thereby eliminating spelling and other errors, and data cannot be saved unless all required fields have been filled. The system tracks whether all metadata elements have been checked, and if so by

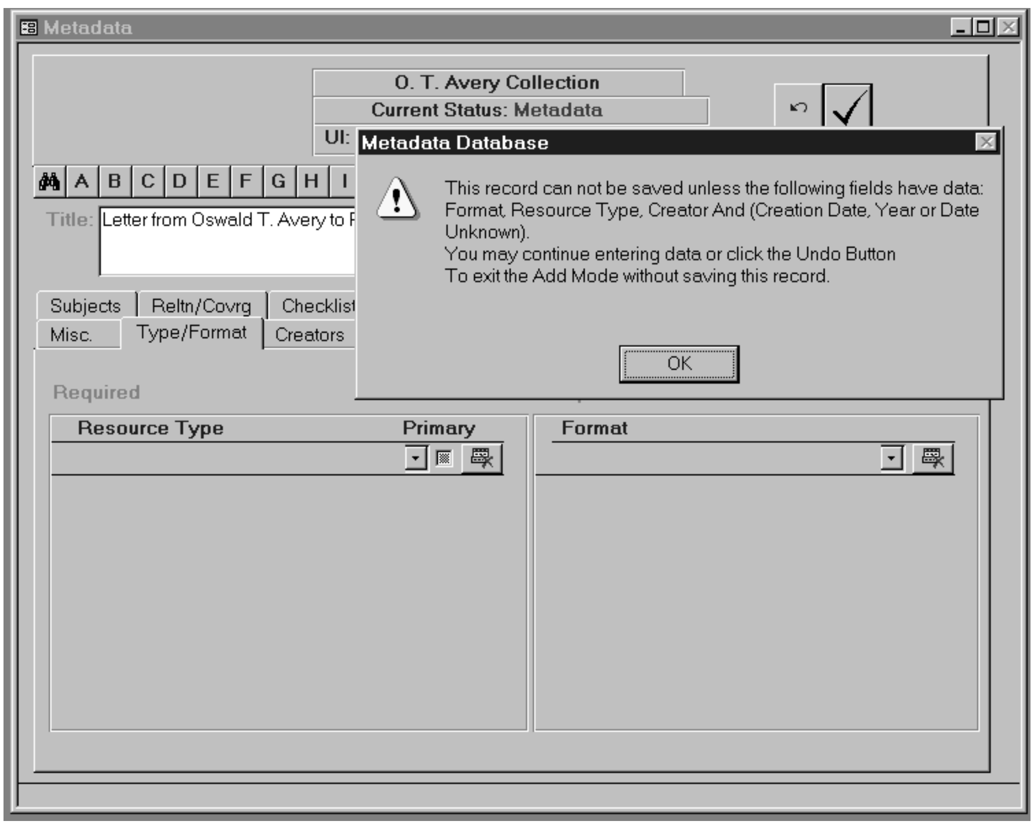

Figure 4. Warning message when obligatory data are missing

whom, when the item was scanned, by whom, and whether it has been checked for quality. Only when all quality control has been completed are the record and digital object released for inclusion in the digital library.

A number of reports can be created from the metadata entry system, which further manages the workflow. These reports can be displayed on the screen as well as printed for further use. Certain types of summary reports are also available. For example, full lists of the standard elements (e.g., journal names) can be displayed for further analysis. The user may wish to view the record just created, and in that case a metadata report is displayed. A summary of all items currently in the collection can be displayed which includes unique identifiers, titles, formats and document types.

A complete status history can be printed that shows all the phases through which a document has passed up to that point. Various statistics can be gleaned from the system, including all work done in a recent month, or overall statistics on the number of items that have been processed in each collection to date.

Security measures are also in place. Entry to the system is by password only. Information may only be read, entered, modified, or deleted based on the user profile. Each user's rights can be further customized relative to the metadata fields, status information, printing, modification of standard lists, and system administration. Further, they may be restricted to certain collections and may not log on more than once at any given time. A log is kept of all individuals accessing the system, including time of entry and exit.

4.2. Display and organization: foundation for Web delivery

The metadata RDBMS is the foundation for the Web delivery system. A series of programs generates the HTML which allows the documents to be browsed over

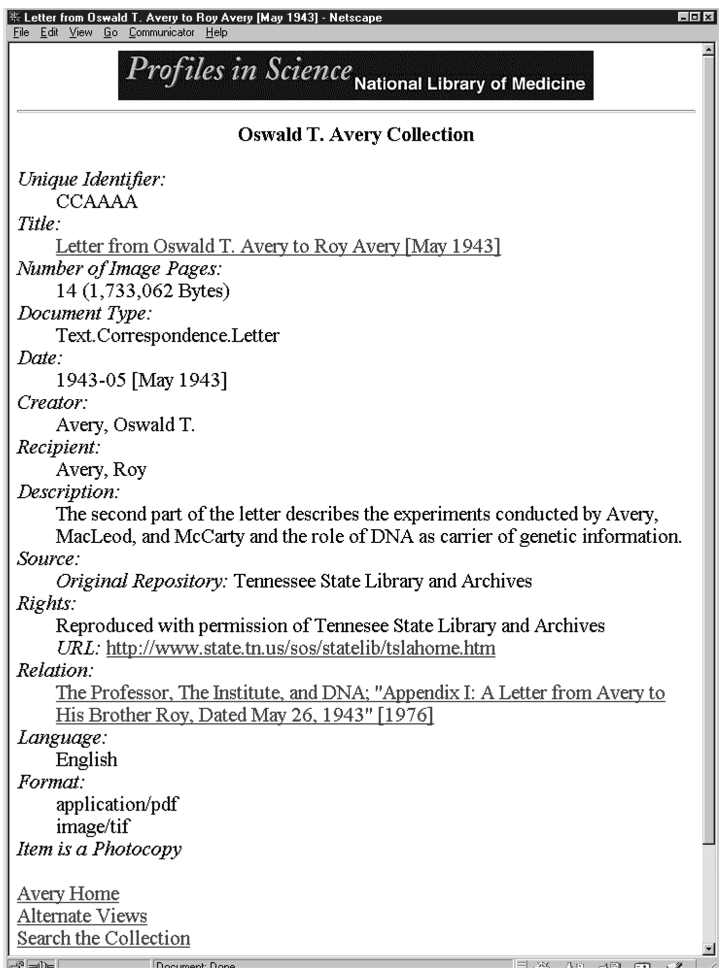

Figure 5. Sample metadata record from the *Profiles in Science* Web site

the Web. The programs read the data exported by the database, and first perform consistency checking among metadata records and within individual records, displaying warning and error messages about the metadata if problems arise. For example, if the archivist has pointed to the unique identifier of a related document in the relation field, and if that related document is marked as not yet being publicly accessible, then a warning message would be printed. Once all validation has been completed, the programs automatically generate HTML versions of metadata records for each item that will appear on the Web site. The metadata record points to an actual document or other digital object on the Web server, and the programs check to verify the existence of these objects. Figure 5 shows a metadata record on the *Profiles* site.

The elements shown in the metadata record that appears on the Web constitute a subset of the information that is stored in the metadata RDBMS and conform to the Dublin Core set of elements. We have also included information about the number of pages and image sizes as well as a note indicating that the item is a photocopy. In the case of the "Relation" field, the title that is printed there has been automatically generated by the programs. The archivist simply entered a unique identifier in the Relation field at data entry time; the system generates the full title.

In addition to automatically generating Web pages, the programs also generate specially formatted lists of URLs and a subset of the metadata elements which are fed to the search engine for indexing the collection's metadata records and digitized objects. Finally, the programs generate statistics that are added to the release history for that collection.

We have designed our programs such that they generate a series of alternate views based on information in the individual metadata records. The views vary depending on the collection. Each collection has an alphabetical (by item title) and chronological view of the items. Within these views the items are organized by resource type. One collection has been organized by "epoch", separated into folders, and assigned identifiers by the donor. Because this epoch, folder and identifier information is entered for each item, a view which reflects this organization is also created. As collections are processed and documents are assigned to permanent boxes and folders, it will be possible to create a view of the items that reflects their permanent locations. Since these views are generated automatically from the metadata, views are updated by re-running the programs using the latest version of the database. In general, any imaginable view can be generated by the program as long as the information exists in the metadata records. The digital images themselves are stored in only one place, according to the unique identifier, but the individual HTML metadata files and the views pointing to them can exist wherever needed. Being able to browse a collection through multiple points of view gives the user an understanding of the collection that might not be obvious from searching or sequential viewing of the items. For example, one can discern almost immediately whether a collection is composed primarily of correspondence or published items based on a view of the collection by resource types.

We have also implemented a variety of filtering mechanisms to address access management issues. Arms proposes a policy-based framework for access management: Each policy relates some group of users with some set of digital material and permits or denies certain types of operations on the material. [14]. In our case, the system is being developed for three types of uses, 1) universal access (freely available on our Web site), 2) access within NLM's History of Medicine reading room only (if so desired by the donor), or 3) access to named individuals only, for some period of time. This latter might be access by digital library staff only until the full collection is ready for release, or it could be access by the donor only until the donor is satisfied that the material may be released. For example, the donor may wish to review the correspondence in the collection to ensure that the privacy of individuals mentioned in the letters is not violated. Other items may be publicly available only for a certain length of time, and renewed permission must be sought, or the item must be removed from public access after expiration. In these cases, a checkbox in the metadata record is used to indicate that the item should not be made available to the public.

4.3. Discovery: standards for resource description

As noted earlier, resource discovery has been the focus of the digital library community's Internet standardization efforts in metadata. The Dublin Core working group has established desiderata for a core set of elements that would be easy for individual authors to use as well as being suitable for larger digital library projects. These are: simplicity, semantic interoperability (useable across potentially disparate subject domains), international consensus, (since the Internet is a global resource), extensibility, and modularity on the Web (allowing co-existence of complementary schemes in an overall architecture, such as the Resource Description Framework). Recently, the working group published an informational Request for Comments on the fifteen basic Dublin Core elements [15]. The document reports on the consensus that has been reached by the individuals participating in the Dublin Core Metadata Workshop series that have been taking place since 1995.

Though the stability of the Dublin Core elements has not been guaranteed, and though the semantics of some of the elements have not always been clear, it has seemed important to us to stay consistent with the evolving standard. We have taken the same view here as in other areas of our system design. We capture a variety of basic information about each of our digital objects, and then we generate the Dublin Core elements from this information. The advantage of this method is that as the Dublin Core develops we can continue to map our generic format to whatever the current Dublin Core elements are. Since the Dublin Core strives to be simple, favoring minimal work by authors, it is unlikely, though possible, that new elements would be proposed for which we do not have the basic information in our system.

5. Discussion

The Digital Library Federation recently defined "digital libraries", as this notion is understood and agreed to by its members:

> *Digital libraries are organizations that provide the resources, including the specialized 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 and economically available for use by a defined community or set of communities.* [12:3].

While one may argue with the assertion that a digital library is synonymous with an organization or institution, it is nonetheless interesting to note the attributes of a digital library that are highlighted by this definition. Selection of material is important, particularly for retrospective projects where it may not be feasible or even desirable to digitize everything in the collection. It may well be the case that a full archival collection will consist of both paper and digital objects, and the digital objects themselves might have arisen from a conversion process, or they might have originated in digital form. The unifying structure for all of these objects might be an archival finding aid, which would point to both physical and electronic locations. The next three attributes listed in the definition are closely related to each other. Structuring, offering intellectual access to, and interpreting collections imply a process of organizing, cataloguing, and indexing material such that it can be more easily accessed and understood by users. Developing a finding aid is the traditional approach for physical archival collections, while assigning metadata to individual items in a collection addresses these functions for digital collections.

Preserving the integrity of and ensuring the persistence of digital works is, in our opinion, one of the most thorny issues in digital library work. There are the technical issues of persistence of hardware and software, and there are the organizational issues involving a commitment to the digital archive, or even the question of whether or not the organization itself survives. A very interesting case is the archive of the now defunct U.S. Congress Office of Technology Assessment (OTA) [16]. Over a twenty-three year history the office created a large number of in-depth reports on a variety of topics. When funding for the office was withdrawn in 1995, the survivability of these reports was in doubt. OTA staff worked to make the reports available electronically and created a fully searchable CD-ROM of the materials. Princeton University mirrored the former OTA Online site and continues to maintain it. What is of note here is that without the intervention of extraordinarily dedicated individuals, these documents and this legacy would surely have been lost.

Digital library projects involve extensive resources, both human and computational. As we design and implement such projects, we need to be mindful of the investment we are making and the commitment that this implies. If we design the system in such a way that it adheres to standards and is extensible, then we have a better chance of ensuring its integrity and persistence. We will still need to track constantly evolving standards, hardware, and software and modify our systems accordingly over time.

Our approach has involved interpreting metadata in its broadest possible sense. We capture data about the items in our digital collection for a variety of purposes and use those data to drive the entire system. The metadata record, together with the unique identifier that is assigned to it, is the basic unit in the system. Using this record we manage the digitization process; we automatically generate views of the collection for our Web site; and we extract a subset of the data, publishing it as Dublin Core, for use in network based retrieval. Since future data and delivery formats are unknown, we have designed our system architecture such that it can easily accommodate changes, while still ensuring the persistence of the underlying data.

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