The Variations and Variations2 Digital Music Library Projects at Indiana University

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‘Variation’ in music is

A form founded on repetition, and as such an outgrowth of a fundamental musical and rhetorical principle, in which a discrete theme is repeated several or many times with various modifications ... The roots of the word variatio in the adjective varius originally referred, in non-specialized antique usage, to an impression of mixed coloration in plants and animals ... Thus from the very beginning we see foreshadowed the twofold musical meanings of variation as technique and as form. (Sisman, 2003)

Variations, a digital library system for music in use at Indiana University, provides near-CD-quality access to more than 8000 sound recordings for students and faculty. Developed at Indiana University in the mid-1990s in part to serve as an alternative to ‘hard-copy’ course reserves in the Library of the Indiana University School of Music, Variations is now heavily used for access to digitized versions of printed and recorded music whether for reserves, classroom, studio or private study use. In February 2003 some 75 classes in the School of Music had placed materials on reserve in Variations, which received an average of 1000 accesses per day.

Variations2 is a research and development project that is currently building a digital music repository linked to a set of applications for the use of music in research and instruction. Its searchable digital database of sound, musical score images, and symbolic score notation may help students, instructors, and researchers analyze music in new ways, forge new relationships with the data, and create new pedagogical approaches. The component-based architecture of the Variations2 system is designed to survive inevitable evolutionary changes in technology. The Variations2 system also serves as a platform for research in related areas, including metadata development, usability/human-computer interaction, networking, and intellectual property.

The Variations2 project is at the midpoint of its initial funding. This chapter reviews the development of Variations and Variations2 and discusses possible future directions in the context of today’s concerns in music research and instruction.

Context: Indiana University and the School of Music

Founded in 1820 at Bloomington, Indiana University (IU) is a major public research university and among the oldest state universities in the Midwestern US. Its campuses include the main residential campus at Bloomington and the large urban campus in Indiana’s capitol, Indianapolis, along with six other campuses across the State.

Indiana University has embraced information technology (IT) as an important tool in teaching and research. All students, faculty, and staff have access to current computing hardware, software, printers, and networks that support work in their areas. Beyond the
university, IU manages the network operations center for the Abilene Internet2 network, and has helped build network connectivity to research and education institutions in the Asia Pacific. This IT-rich setting provides a climate hospitable to research in the application of IT to teaching and research.

The Indiana University School of Music, located in Bloomington, is among the nation’s largest, with some 1500 degree candidates and 150 full-time faculty. The School offers graduate and undergraduate degrees in 22 musical instruments, early music, church music, musicology, theory, voice, jazz, music education, conducting, composition, ballet, audio recording, and stage direction (Indiana University [hereafter IU], 2001). The William and Gayle Cook Music Library serves the School’s faculty, staff and students as its primary clientele, and is also one of the nation’s largest (IU, 2002, William). The collection numbers some 430,000 volumes and 136,000 recordings. Its strengths include: 19th-century first or early editions of orchestral, chamber, and opera sources; extensive holdings of printed operas; theory treatises from the Renaissance to the late nineteenth century; Russian/Soviet music; early keyboard and violin primary source materials; the Black and Latin American Music Collections; as well as other special collections of print and audio materials. (Most rare music items, including a large collection of sheet music, are housed in the University’s Lilly Library.)

In the School of Music, IT gained an early foothold. A graduate elective in computer programming for music research was offered 1967 and in 1968 a computer music studio was built, housing a mini computer. In the mid-1970s professors developed instructional programs for aural skills and established a music learning lab. By 1989, the School had created the position of director of computing for the School of Music.

With the growing importance of digital information the Music Library turned to digital means for distributing that information. In 1987 the installation of a Novell network made it possible to distribute text, computer-assisted instruction programs, and music notation sources over a network, rather than to standalone workstations. This digital traffic accounted for only a portion of library circulation. Music students routinely requested more than 5500 sound recordings per month, many requesting the same materials at any given time. To preserve fragile originals and provide multiple copies for circulation, librarians dubbed copies onto cassette tapes, with some loss of audio quality. A system that could offer multiple patrons simultaneous, high-quality access to sound over a network was seen as an immediate solution to a host of issues (Burroughs and Fenske, 1990).

Variations: Beginnings

The sound component was the first phase of Variations to be developed. The convergence of various technologies in the early 1990s — high-fidelity PC audio hardware, streaming multimedia servers, hierarchical storage management systems, and the Web — enabled the development of the first Variations prototypes. In addition, the construction of the new Cook Music Library facility provided an opportunity for funding and large scale implementation of such a multimedia delivery system. Built using a combination of internal funding from the School of Music, the Libraries, and University Information Technology Services, and in-kind donations of equipment and software from IBM, Variations was first tested in the spring of 1996 as a reserves system for sound recordings in a large undergraduate music theory class. Later that year Variations
provided the platform for all course audio reserves in the Cook Music Library. It could stream high-fidelity recordings to library workstations, seminar rooms, and staff workstations and quickly became a key part of the Library’s support of teaching in the School of Music.

The technical development of Variations involved more systems integration than straight software development. Commercial hardware and software products were combined with components developed at IU to create a client-server environment based on an ATM network and IBM streaming media and storage technologies.

In its current configuration, the Variations system consists of an archive server (IBM RS/6000 with attached IBM 3494 tape library and three IBM 3590 high-speed tape drives), which stores the primary copies of sound files, and a playback server (another IBM RS/6000 running IBM VideoCharger software), which caches recently used files on a hard disk array for streaming to clients. This two-level storage hierarchy reflects the typical usage pattern of an academic library, and particularly of course reserve use, in which at any given time only a small portion of the collection is actually in use. Locally written software ties the two servers together and provides a Web user interface. The current configuration is very similar to the original one deployed in 1996, but with additional storage capacity and updated software. In addition, the ATM network has been replaced with less expensive switched Ethernet technology.

Content is captured for the system by student technicians in the Music Library working at digital audio workstations. They create CD-quality sound files from analog or digital media in Microsoft’s WAV format at an audio sampling rate of 44.1 kHz and sample size of 16 bits with two channels, the parameters used by audio CDs and supported by common PC audio playback hardware. These WAV files are transferred each night to the archive server, where they are converted into MPEG-1 layer II format at a compression ratio of 3.6:1, reducing storage requirements while keeping sound quality high. The WAV files are stored offline on tape, while the MPEG files are kept available in ‘nearline’ storage on tape in the archive server.

Metadata for recordings in Variations consist of the existing USMARC (MARC, 1999) bibliographic records in IU’s IUCAT online catalog system, plus ASCII text metadata files in a locally defined format. These metadata files contain additional technical and structural metadata used in navigation and management of the digital sound files.

Variations sound recordings are delivered to some 100 Windows computer workstations, scattered throughout the Music Library and equipped with sound cards and headphones. Many are also equipped with MIDI synthesizers/keyboards. These workstations, now managed as a student computing lab by IU’s University Information Technology Services, also deliver basic computing functions including e-mail and word processing, library-specific functions (such as access to CD-ROM databases and the online catalog), and music computing functions, including software for ear training, music notation editing, and composition.

To use Variations, a student launches a Web browser to the Music Library Home Page, clicks the ‘Course reserves’ link, selects a course number, and chooses the recording from a list organized by composer and title. Access to Variations recordings is also possible through links from records in the IUCAT online catalog system and from faculty-created course home pages. The locally written Variations Player application (see
fig. 1) is used to control playback, allowing the user to navigate easily to particular tracks or time offsets. A single user can open multiple files at once to study comparisons between performances, and any number of users can listen to the same file at any given time, yet have independent control over playback. On an experimental basis, scanned versions of some printed musical scores have been made available to supplement the recordings in Variations, but the system is not as fully developed for scores as it is for recordings.

The term ‘Variations’ was chosen for its resonance with the musical form, ‘theme and variations’, and as it alluded to the musician’s need for material in a variety of formats, including text, sound, video, music notation, and images, in an integrated setting. This system provided a variation on the traditional means of delivering sound and an alternative to the standard method of checking out hard-copy library materials placed on reserve. Developers also assumed the system would continue to be refined to handle the multiple formats in which scholars study music: score, sound, text, video, and so on. The plural form of the name captures the nature of Variations as a work in progress.

Variations was unique at the time in creating a digital music library, not merely an audio reserve system. Since then several major projects have digitized discrete collections of music in their entirety, and academic music libraries have developed digital audio reserve systems of various sorts. But Variations launched a cycle of development that enables new relationships between researchers and their data, and allows for new ways of teaching and conducting research. Variations and its subsequent iterations promise to open the doors to new ways of studying music. As happens when technology is applied to the study of any academic field, invariably new landscapes of inquiry suggest themselves. And these in turn suggest new ways of applying technology to deepen and enrich the study of the field. The next generation of the system, Variations2, illustrates this point: it not only extends the technical capabilities of Variations, but also serves to support research in related areas, including metadata development, usability/human-computer interaction, networking, and intellectual property.

**Variations2: The next evolution**

The Variations2 project became one of the first modules in Indiana University’s Digital Library Program (IU, 1997–2002), which was established in 1997, and is a collaborative effort of the Libraries, the Office of the Vice President for Information Technology, the School of Library and Information Science, and the School of Informatics. Its broad program of collections and activities promotes the scholarly use of digital content and networked information. Research and development projects connected with it extend the state of the art in digital libraries and help develop understanding of the organizational, technological, and human factors involving the use of digital libraries.

In support of Variations2, in September 2000, Indiana University was awarded three million dollars by the Digital Libraries Initiative, Phase 2 (DLI2), a multi-agency US federal program with funding from the National Science Foundation and the National Endowment for the Humanities, in response to a proposal entitled, ‘Creating the Digital Music Library’. Seventeen faculty and staff investigators from two campuses (Bloomington and Indianapolis) were assembled from University Information Technology Services, the Libraries, the School of Music (on both campuses), the School of Law (Indianapolis), and the School of Library and Information Science, under the
direction of Michael McRobbie, IU’s Vice President for Information Technology and Chief Information Officer. In addition, seven other institutions (three in the United States, three in the United Kingdom, and one in Japan) had agreed to participate as satellite sites. Simply put, Variations2 intends to ‘move digital music libraries into a new phase — beyond creating, organizing, and dissemination digital objects — to the seamless immersion of digital content into the education and research process.’ (IU, 1999, p. 4)

The Variations2 system under development moves far beyond the first iteration of the Variations project in that it provides a far more complex layered array of repositories, access and user interface components, and applications. While the only searching mechanisms in Variations were the university’s local online catalog and/or Web-based reserve lists, the Variations2 project is developing its own descriptive, structural, and administrative metadata. While in Variations the digitized file formats were limited to audio and graphic images of musical notation, Variations2 adds digital music notation and video. The project will also seek to integrate content-based music information retrieval technologies developed by other researchers. That is, by encoding musical incipits (themes), or even a complete musical work in a digital music notation format, we intend to provide the ability to search by means of the music itself (themes or phrases or entire works) as well as by the ‘name’ of the music, or some other attribute such as the composer or performer.

The system also provides multiple interfaces, not only to take advantage of new kinds of files, but also to present them in different ways to teachers, learners or researchers, and system administrators. While Variations presented simply an audio player or page image viewing screen, Variations2 offers possibilities for greater interaction with the music itself. Further, Variations2 has its own search and administrative (cataloguing) interfaces so no longer depends on other systems for those functions. Using ‘bookmarks’ the user can capture and save references to small portions of a musical work, however they are represented, for close comparison with iterations of similar phrases elsewhere in the same work or in other works. Facilities for synchronizing graphic representations (musical scores) with audio representations (recordings) are being developed, so that one may see and hear and bookmark the representations simultaneously, allowing freer concentration on musical cognition. (It will be possible to disengage the synchronization when teaching score-reading skills.) An interface is also being developed that permits the student to analyze the melodic and harmonic content of a work through bubble diagrams, and present the work as an assignment to be corrected by the instructor.

Using Variations2

The search process in Variations2 has been designed specifically for those who are knowledgeable about music repertory. Metadata are stored so as to maintain the rich relationships among people (composers, performers, and the like), works (conceptually defined), versions (performances, notational representations), and containers (specific albums or editions) in order to provide musicians with a more intuitive and meaningful searching and browsing experience. When users initiate basic or advanced searches, they progress through a series of screens that allow them to specify the components of their searches (see fig. 2 for an example). For example, some contributors have multiple roles as agents with respect to a given piece of music. Leonard Bernstein was a composer,
arranger, and pianist; he also conducted his own works and those of others. Users of the advanced search can immediately narrow their searches beyond composer and title by using fields for other contributors (performer, editor, arranger), format, key and mode (major, minor). These enhancements make search results far more specific and reduce the number of times users must comb through the unsorted sets of results often generated by online catalog searches.

Once a user chooses a version of a work, some type of player or viewer opens, depending on whether the user has chosen a musical score, an audio piece, or a video recording. Navigation in Variations2 will be considerably more sophisticated than in Variations, thanks to a hierarchical, nested display of whole works, parts of works, analyzable sections within a part, and in some cases granularity to the exact measure of the work (see fig. 3).

Variations2 has moved far beyond the original concept of a digital library to take its place in the interactive classroom. We have integrated Variations2 content into a music appreciation course for the non-major studying at a distance via ‘Oncourse’, IU’s online course management system. Assessments will compare the effectiveness of a lecture-based class supplemented with digital content to one presented fully online, including threaded discussions. An instructional authoring environment, designed for faculty teaching music theory and other courses for music majors, will support the creation of classroom presentations and student lessons in musical melodic and harmonic analysis. These lessons will integrate and synchronize the digital library’s holdings, a music notation editor, form diagrams and other music visualization techniques, and provide the ability to pose questions and accept and evaluate answers.

Variations2 system architecture

Successful digital library systems must offer persistent access to their content despite the inevitable technological progress that will occur over their lifetimes. There is great risk of building systems with excellent functionality that will disappear when file formats, storage media, hardware, software, or other technologies become obsolete. In addition, to be truly useful, digital library systems can no longer be standalone monolithic systems. They must be able to be integrated into the larger digital information environment, including course management systems, the online library catalog, and licensed, externally served information resources.

The system architecture of Variations2 has been conceived from the start as modular, open, and extensible, and is being built with the assumption that there will be multiple pathways through which users discover and access its contents, along with multiple user interfaces for various tasks. Variations2 is viewed not just as a self-contained digital library system, but also as a platform for the development of additional domain-specific applications that use the contents and services of the digital music library.

Conceptually, the Variations2 system architecture has been envisioned as a series of abstraction layers that separate the functions of the library and define the interactions between these functions (see fig. 4). At the base of the architecture are repositories of content (audio, score images, score notation, video) and metadata. Above these repositories sits a layer of system services or application program interfaces (APIs) for searching and retrieving data from the repositories. Above the system services are user
interface (UI) ‘components’ that expose these services in a form that users can use. Some of these UI components are relatively straightforward, such as a metadata search tool, a sound player, and a score image viewer. However, others offer a greater degree of interactivity and specialized features that go beyond search, display and playback. Examples of the latter include a synchronized score viewer and sound player and the Timeliner tool for creating diagrams of musical form using content from the library. Finally, at the top lie the actual software applications through which users interact with the library. These software applications integrate the underlying UI components with additional interfaces to create a fully functional environment in which the user can accomplish various categories of tasks.

Variations2 is being developed primarily using the Java programming language. The object-oriented nature of Java lends itself well to the implementation of a modular architecture as described above. In addition, many class libraries are available as open-source or freely licensable commercial products to help with such issues as XML processing and streaming media playback. For ease of implementation, since both client and server are being written in Java, we have used Java’s RMI (Remote Method Invocation) as the communications mechanism between client and server. Ultimately, a more language-neutral solution may be preferable.

Repositories

The underlying metadata repository has been implemented using IBM’s DB2 relational database software running on IBM’s AIX operating system. However, Java classes sit on top of DB2 to shield access components and applications from the implementation detail of the repository. These classes also serve to translate metadata records to and from an XML-based representation for purposes of data import and export. This should allow us to substitute other relational databases or data storage mechanisms (for example, a native XML database such as Software AG’s Tamino) with relative ease, with little or no change to other parts of the system. The audio content repository is implemented using Apple’s Darwin Streaming Server open-source, RTP/RTSP-based media server running on Linux. The score image repository uses a simple Apache Web server, also running on Linux. Audio content is currently stored using Apple’s QuickTime file format, which can accommodate a number of different content codings, including MP3 and MPEG-4 AAC, and is controlled at the client via Apple’s QuickTime for Java API. Image content is stored in the DjVu format, originally developed by AT&T Labs, which we have found offers much better zoomable onscreen display for scores than such other formats as PDF. Again, for both image and audio access, components at the services layer isolate the UI components and applications from the implementation detail and allow other multimedia formats and delivery technologies to be substituted in the future. Master copies of both image and audio content are also stored offline in TIFF and WAV format, respectively.

Because we are dealing with copyrighted content, we must provide the ability to control access based on properties of both the content and the user. Initially, we are securing access by requiring users to authenticate with a personal username and password. For IU users, this is accomplished using IU’s existing Kerberos authentication infrastructure. For satellite site users, we are initially handling user management ourselves by running our own Kerberos server, but we hope to be able to integrate with
such emerging technologies for cross-institution authentication and authorization as the Internet2 project’s Shibboleth architecture (Internet2, 2003). As intellectual property requirements are further defined, we will be able to design additional access controls.

In any system involving streaming media delivery, network performance, including the minimization of packet loss and jitter (variation in the pace of packet arrival), is a key concern. We had originally intended to identify various network quality of service (QoS) methodologies that might be appropriate for the streaming delivery of highly interactive multimedia and to engage in implementing and testing these QoS methodologies in a local laboratory as well as via our network connections to satellite sites. However, the fact that all of our satellite sites are now connected to high performance research and education networks (such as the Internet2 Abilene network in the US) which generally have bandwidth to spare, combined with some fundamental viewpoint changes within the QoS research community (principally a shift in responsibility for dealing with QoS issues from the network hardware to applications) has led us to take a slightly different focus. We are studying the performance of our application through user feedback and data supplied by network instrumentation and are using this information to determine network requirements for scaling up Variations2 use and to make recommendations for tuning application parameters, particularly QuickTime Streaming parameters.

User Interface Components

The primary user interface components include the following:

**Search Tool:** The search tool is the primary interface through which users locate digital music content in the system by searching or browsing descriptive metadata. Unlike traditional library OPAC (online public access catalog) interfaces, ours is specifically designed for music content, with search fields labeled using musical terms (e.g., performer, composer) and the concept of the musical ‘work’ as embodied in our data model prominently exposed to bring the various instantiations (recordings and scores) of a given work together in the interface. Basic, Advanced, and Keyword searches are available. In the Basic and Advanced options, rather than being taken directly to a result set of recordings and scores, the user is walked through a series of ‘disambiguation’ steps in order to clarify the composer, performer, and work entered, and is ultimately brought to a list of instantiations (recordings and scores representing individual works) rather than a list of containers. The selection and arrangement of search options were informed in large part by looking at user needs through inspection of logs of inquiries at the Music Library reference desk and discussions with library users. For example, because most music searches are for some form of ‘known item’ (e.g., the user has a composer, performer, and/or work title in mind), these are the fields present in the Basic search option.

**Sound Player:** The function of the sound player is to play back sound recordings from the library’s collection. In addition to the standard CD-player-like controls found in all sound players (e.g., play, stop, pause, and so forth), the interface also provides navigation within a given sound recording through the use of structural metadata stored in the system. Two means of navigation are available: users may view a list of the ‘tracks’ or ‘bands’ from the original recording and move forward/backward between tracks, or click on a track title to jump to a specific track. In addition, users may navigate
based on the structure of the musical work using an outline of the work structure that is consistent across all instantiations of that work in various recordings and scores. For example, all recordings of Beethoven’s fifth symphony would be accessible by movement. This is accomplished through the work structure/structural binding facility of Variations2 metadata, discussed later in this chapter. In future versions, we will extend the capabilities of the sound player to video.

*Score Viewer:* The score viewer provides similar navigation functionality for digitized images of printed musical scores, offering standard image viewer controls (forward/backward page, zoom, and so on) along with structural navigation based on the underlying metadata. The ability to print a score (depending on access controls) is also available.

*Bookmarks:* Both score viewer and sound player provide access to a bookmarking function that allows users to mark time points or page offsets in recordings and scores for future use. Variations2 bookmarks may be relabeled and arranged into folders, similar to Web browser bookmarks or favorites.

*Sound-Score Sync Tool:* The sound-score synchronization tool will allow a user to open a score and sound recording of the same musical work and seamlessly navigate through the two together. The most basic manifestation of this is ‘automatic page turning,’ e.g., while the sound is playing, the score will turn pages to follow the performance. Perhaps the more useful capability is being able to turn to a specific page in the score or enter a specific measure number and have the sound recording move to that same point. Sound-score synchronization is initially being implemented using a single window that combines sound player and score viewer controls. This simplifies the user interface over the alternative of having multiple sound player and score viewer windows synchronized to each other, but has the limitation of allowing for only one sound recording and one score to be in use at any time. Synchronization would also be useful for multiple recordings (e.g., comparing performances) or multiple scores (comparing editions).

*Timeliner:* The Timeliner tool can be used to create musical form diagrams using a simple ‘bubble’ visualization. A horizontal line represents a section of sound from a recording in the system. A nested series of bubbles may be created above this timeline to indicate sections and subsections of the work, and these bubbles may be color-coded and labeled to illustrate repeating elements of the music. These diagrams may be saved to disk or printed for presentation.

*Score Notation Viewer/Editor:* This tool, which has not yet been designed or developed, will be used to display digital music notation content from the library, in a similar fashion to the score image viewer. However, the use of music notation stored in a logical representation potentially allows for much greater capability than exists with score images, including the ability to zero in on particular parts or to play back the score to a MIDI instrument. There is also a possibility for providing some basic editing functions, which may be particularly useful in classroom teaching situations, though we will have to be careful to define the boundary between our tool and full-blown music editing software packages such as Finale and Sibelius, to which we should be able to export our content for cases when advanced editing is necessary. One major issue with score notation is choice of file format. Many music representation formats are available,
both proprietary and open, but no true standard or clear best choice exists. We are evaluating a number of different options (Byrd and Isaacson, 2002).

**Applications**

We are currently focusing on a core digital library access application that provides search, retrieval, and viewing capabilities using the components identified above. However, we plan to work on other applications, including an authoring environment to support faculty and instructional developers in the creation of online educational materials that make use of digital library content. This application will allow users to create multimedia documents by assembling a set of Variations2 content and UI components (e.g., sound player, score viewer, Timeliner), supplemented by additional components for text display, question-drilling, and other tasks, into classroom presentations and independent exercises for students. Such capabilities will allow instructors to easily play music selections, view scores, illustrate musical concepts through the use of music notation and form diagrams, and assess students’ abilities to hear, understand, and categorize music.

We have created prototypes typical of the sort of lessons and presentations that could be created using such a tool in order to help evaluate their usefulness and guide our design of this authoring and delivery environment (see fig. 5).

**Metadata**

The metadata research in Variations2 is ambitious in that it attempts to develop a data model that permits searching, retrieving, displaying, navigating and documenting musical works while preserving their musical relationships. Current local online catalog systems based on USMARC do not adequately support these activities, chiefly because of the particular characteristics of musical works: high incidence of multiple authorship (Papakhian, 1985); works known under various titles in the same or different languages; and the presence of multiple works in one publication, particularly recordings, so that it is difficult to associate attributes (composers, performers, descriptors, duration) with individual works. Musical works are manifested and digitized in various formats other than text: printed music (‘scores’) digitized as graphic images and notation files, audio recordings, and video. Some characteristics are shared among different instantiations of the same work, and some differ. Each music search query is uniquely constructed from various types of attributes, and individual users want to navigate search results differently.

Thus we have defined descriptive, structural, and administrative schemas. The descriptive metadata build on the well-established USMARC format for transmission of bibliographic information. But we have defined four levels of entities in order to preserve the relationships among them (works, instantiations, containers, and media objects), and a fifth (contributors) to establish the agents of their creation at any one of those levels (see fig. 6).  

The first level is conceptual, representing the ideal ‘Work’ (individual or collective) and what we know about it (link to a creator, statement of form or genre, instrumentation, key if applicable, named divisions, date and place of composition and first performance if known), accompanied by source documentation.
The ‘Instantiation’ record represents each individual performance or graphic version found in a ‘Container’. Contributors associated with instantiations are performers, and editors or directors (of videos) and the like. Some of the descriptive information associated with an instantiation varies from that of the associated work (e.g., date of performance), and information about the extent of the work is added (duration, pages). ‘Container’ records are minimal, combining information about a published recording or score (e.g., titles, publication or release dates, and so on) with links to the instantiations for all of the works present.

Three principal types of structural metadata have been defined in Variations2: ‘container structure’, ‘work structure’, and ‘work bindings’. Container structure serves to identify the physical items (e.g., CDs, LPs, score volumes) that make up a container, as well as the subsections within these items (e.g., sides, tracks, pages), to facilitate navigation of a digitized recording or score as if the physical item were in hand. Work structure is used to identify and describe the discrete hierarchical elements of a given work. The discrete elements may be labeled with titles appropriate for their internal compositional sections (e.g., arias or movements). These sections may be further subdivided by labels indicating such formal components as exposition, development, recapitulation, da capo, and so on. The finest granularity may be marked by labeling measure numbers. Work bindings are associated with each instantiation and serve to tie particular time or page ranges within the media objects of a given instantiation to the abstract structure of the corresponding work.

The administrative metadata comprise data that allow us to track various kinds of information about the metadata creation (sources of information and vocabulary), as well as the status of record creation or update, digitized media information (file format, compression, bit and sampling rates, resolution, hardware and software used), copyright declarations, access control, and for containers, any external standard numbers and statement of condition (for preservation purposes). Our intention is to record any information needed to migrate or preserve this development in future technology, and we plan to make use of emerging standards in this area, particularly for technical metadata, e.g., the MIX standard for images (Library of Congress, 2002, NISO) and the work being done by the Library of Congress on audio and video technical metadata (Library of Congress, 2002, Digital).

An illustration of the data model with examples may be seen in fig. 7.

We are importing existing score and sound objects from Variations and mapping some data from USMARC records for the original containers to Variations2 so as not to duplicate that effort. We are teasing apart the descriptive elements devised for physical artifacts and are associating the data instead with digitized works and instantiations. Although we have been criticized for remaining too dependent on the USMARC format, we find this level of detail useful, particularly in authoritative headings and controlled vocabularies, in providing successful navigation among the entities. But if our project is to become internationally cooperative, we may need to look at other standards as well, and at the very least develop a crosswalk from our descriptive metadata to the Dublin Core standard and/or the emerging Metadata Object Description Schema (MODS).

We established our metadata entities based on earlier conceptualization about music in descriptive catalogs by Richard Smiraglia and Sherry Vellucci, who in turn derived theirs in part from that of their mentor Barbara Tillett. Tillett was a consultant.
to the International Federation of Library Associations and Institutions’ Functional Requirements for Bibliographic Standards (FRBR), a final draft of which was issued in 1998 (IFLA, 1998). Future work will examine how we might better exploit FRBR, since our metadata construct is so similar, with a view toward exploring how metadata entry could be encouraged and facilitated in a distributed fashion. One of the major bibliographic networks in the United States (OCLC) is preparing to implement FRBR, but there are currently no plans to implement it for music. We will also investigate other appropriate standards such as the Metadata Encoding and Transmission Standard (METS) (Library of Congress, 2002, Metadata) and the Moving Picture Experts Group’s MPEG-7 and MPEG-21 designed expressly for digital objects (Fraunhofer, 2001, MPEG-7 and Fraunhofer, 2001, MPEG-21). It has also been suggested that we devise administrative metadata that would track the kinds of uses being made of these objects (assignment preparation by classroom or studio faculty or student, recital-program design, background listening, mood music) to facilitate our research with respect to intellectual property.

**Usability**

Usability is a primary research focus of Variations2, with the aim not simply to create a digital library system that is easy to use, but one that actually proves useful to its target user population. By integrating a user focus into the system design and development process, we can help to ensure that we meet this goal.

The project’s Usability Specialist is an integrated part of the software development team, helping the team to define system requirements based on user needs as documented through a variety of methods. Usability work on the project has included three primary activities: (1) study of current user practices in order to establish a usability baseline for future comparison and help guide design decisions; (2) investigation of emergent interaction technologies which may be of benefit; and (3) usability evaluation of the Variations2 system through contextual interviews, lab-based testing of prototypes and finished releases, and pilot studies of actual use.

Study of current practice has been accomplished via a usability test of the existing Variations system, a satisfaction survey of current Variations users, and by contextual inquiry into music classroom pedagogical practices, Variations use in the Music Library, and the information habits of voice students. These studies revealed a generally high level of satisfaction among users with the current Variations system; however, some complaints were noted, including latency in requests for recordings and in moving around within recordings and the fact that access is restricted to within the Music Library. User interviews using paper prototypes help to validate user interface and information architecture design concepts before the expense of implementation, while lab-based testing allows us to make adjustments to the user interface before the system is widely deployed to users. Finally, pilot studies in which the project Usability Specialist works with faculty and students in the context of a specific class unit or assignment allow us to examine the system in real-world use rather than in the more contrived setting of a lab-based usability test. To date, two methods have been used to gather data during pilot studies: automated logging of user actions and a Web-based satisfaction survey.

Of all these activities, the most fruitful in terms of identifying system design issues have been usability testing and observational studies. Both methods yield rich data about users’ experiences with the system, and both methods provide enough context to
render the data meaningful and actionable. Surveys and session logging have been less valuable because it is difficult to know what thought is behind a particular mouse click or Likert scale rating.

Future usability work will include broadening the scope of our studies to include the satellite sites, so that we can be more certain that the Variations2 system will be applicable generally and not just to IU. We will continue to engage in prototype testing and lab-based usability testing of current and future versions of the system and will also conduct field studies of Variations2 use and of the ways instructors prepare lessons and use technology in the classroom.

**Intellectual property**

Variations2 embraces research in intellectual property, given that the issues are complex in a digital music library that will be shared with public and private institutions in three different countries. Although the US Copyright Law is generally more liberal than its Canadian or European counterparts, particularly in its concept of Fair Use, the digital issues are complex and confusing. Music libraries have depended on the Fair Use provision more heavily than have other libraries because of the generally more restrictive rubrics for music in Section 108 of the US Copyright Law (exceptions for libraries). Exceptions for performance and displays (in Section 110) are generally limited to face-to-face teaching, although the recently enacted so-called ‘TEACH Act’ has broadened these somewhat (Technology, 2002). At issue, however, is whether or not libraries may make digital copies of documents they have lawfully acquired for the purpose of digital display, as they did for photocopying or microfilming, in the context of teaching and learning in nonprofit educational institutions.

Kenneth Crews has written a number of working papers for Variations2 research examining the constraints of Sections 107 and 108, and the difficulties of establishing whether or not something is in the public domain (Crews, 2001). Naturally we will exercise our right of Fair Use to the extent possible, but we are also watching as the music industry attempts to establish new business models in a period of rapidly declining sales and confusion of new media standards. It appears that given the failure of the marketplace to establish convenient and cost-effective methods of licensing musical content, reliance upon Fair Use is our only option at the moment. Based on observations gleaned from our usability studies, we are creating a set of scenarios that we will test to see how broadly we might interpret this doctrine. Because the project is underway in geographical areas with three different sets of intellectual property laws, we will need to develop a complex grid of rights management with corollary rules for users’ access and authentication.

**Conclusions**

The Variations2 project is a true work in progress. It serves as a platform for research in six different but closely related domains: metadata, usability, pedagogy, intellectual property, networking, and system architecture, and provides a basis for useful experiment that will address issues identified in our grant proposal. We also continue to investigate emerging technologies such as content-based music information retrieval, which could prove useful to music digital library users.
As Variations2 develops, we continue to ask questions that touch on many aspects of the system and its users. Are we creating a digital library system that can be used in production at one or more of the music libraries involved in this work? If so, how do we integrate it within other existing local systems, or should we? In a project involving more than one library, what are the political issues involved? How will governance be determined? Will the music industry develop convenient and cost-effective licensing plans relevant to the use of music teaching and research in a non-profit educational environment? How far can or should we extend the concept of fair use in a multinational project in order not to limit our library to music in the public domain? Are any of the existing metadata schemas more appropriate, or should we continue to develop our own? How can we lessen the intensity of the labor now necessary to populate Variations2 with authoritative and navigable media objects and thus reduce the costs? How may cataloging and digitization efforts be shared? What kinds of networking designs are necessary to provide interactive access to the system to all campuses of the same university, and to other universities in the United States, the United Kingdom, and elsewhere? Is the system architecture we are developing sufficient to support all these activities?

In designing the current system, we have made choices with future expansion in mind, but work will need to be done to add support for sharing metadata records and content between Variations2 repositories at different institutions. Also, depending on outcomes in the intellectual property area, increased authentication, access control, and digital rights management functionality will need to be provided.

Another question to address for the future is that of how to continue development of the Variations2 software. A number of models are possible. At first glance, given the economics of music libraries, it seems unlikely that a commercial spin-off could be a success, but that option may merit further investigation. Another more promising option might be to form a collaborative development project among the set of institutions using the software. This could be carried out as a ‘pay to play’ model in which institutions contribute development efforts in order to have access to the software; alternatively an open source model would allow free distribution of the software and source code to any interested user.

In order for Variations2 to be successfully deployed in production at multiple institutions, more work is needed to make it adaptable to a wider variety of technical environments (in terms of server hardware, operating system, and database platforms). In addition, many institutions, either driven by their libraries or by their IT organizations, are starting to look at implementing institution-wide digital library repository systems or digital asset management systems. These systems include those born in the academic world, such as Fedora (Fedora Project, 2001) as well as commercial systems such as IBM Content Manager and Artesia TEAMS. Variations2 will need to be able to make use of such systems for content and metadata storage if it is to be integrated into university structures for supporting digital content.

Finally, to be successfully integrated into classroom and distance education, Variations2 must be able to interoperate with course management systems beyond IU’s own Oncourse system. Several efforts to standardize course management system interoperability are starting to emerge, including the Open Knowledge Initiative (OKI) effort (Massachusetts Institute of Technology, 2002), in which IU is a participant.
‘. . . Thus from the very beginning we see foreshadowed the twofold musical meanings of variation as technique and as form’ (Sisman, 2003). The Variations2 project creates and relies on a vast array of techniques to construct a form with many dimensions. The idea of a searchable digital library, even for music, is certainly not new. What is new, and of significance, is the creation of a working, extensible model that accommodates searching, display, and navigation among music in all its formats, for a variety of uses in personal and classroom learning and teaching, in many academic institutions.

Acknowledgments

We would like to thank Mark Notess and Doug Pearson for their assistance with this chapter. We would also like to acknowledge the work of present and past members of the Variations and Variations2 project teams in the development of these systems. This material is based upon work supported by the National Science Foundation under Grant No. 9909068. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.
Figure 1: Variations sound player application

Figure 2: Variations2 search interface
Figure 3: Variations2 sound player

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<th>Audio</th>
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<th>Score images</th>
<th>Score notation</th>
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<thead>
<tr>
<th>Search</th>
<th>Sound and video playback</th>
<th>Image retrieval</th>
<th>Score retrieval</th>
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<th>Search tool</th>
<th>Sound/ video player</th>
<th>Score viewer</th>
<th>Digital Timeliner</th>
<th>Cataloging tools</th>
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<td>General purpose library application</td>
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<td>Multimedia Music Theory Teaching application</td>
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<tr>
<td>Oncourse</td>
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<tr>
<td>Cataloging/ administration application</td>
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<th>User Interface Components</th>
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<tr>
<td>General user</td>
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<td>Theory student or instructor</td>
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<td>Non-major music student or instructor</td>
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<td>Cataloger or digitization technician</td>
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Figure 4: Layered view of Variations2 system architecture
Figure 5: Music theory lesson prototype
Figure 6: Variations2 data model

Figure 7: Variations2 data model example
Bibliography


For detailed technical descriptions of Variations hardware, software, networking, and methods of sound capture see especially Dunn and Mayer (1999).

For a recent brief survey of these projects, see Davidson (2001), 400-402; Griscom (2003) surveys digital audio reserve and preservation projects in music libraries.

The institutions were Northwestern University, University of Illinois at Urbana-Champaign, University of Massachusetts at Amherst (United States); King’s College London, University of Loughborough, and University of Oxford (United Kingdom); and Waseda University (Japan). City University London has recently become an additional site in the UK.

For further information on music information retrieval research, see Downie, 2002, and the online proceedings of the ISMIR conference series at http://www.ismir.net/

Bamberger (2003) has shown that a curriculum for elementary music fundamentals classes at the college level should recognize, build on, and help students develop their musical intuitions in part by giving easy access to ‘a variety of representations’ that include: multiple sensory modalities, multiple graphics and multiple levels of musical structure.

For more detailed description of the various interfaces, see IU (2002), IUDML.

This software was developed at Indiana University. For a description, see IU (1997-2003). For an overview of the specific application, see Fern, Lindsey, and Scull (2002).

For commentary on the music appreciation and music theory applications, see Isaacson (2002).

For a detailed chart showing the details of the entities with their associated types of metadata, see Davidson, Hemmasi and Minibayeva (2002). See also Minibayeva and Dunn (2002).


Smiraglia (2002), Vellucci (1997) and Tillett (1987). These sources provide insight into Smiraglia’s and Vellucci’s most recent writing about the nature of musical works, and Tillett’s seminal thought upon which they are based.

See also Tillett (2001).

METS grew out of the Digital Library Federation’s ‘Making of America II’ project (Digital Library Federation, 2001) and is maintained in the Network Development and MARC Standards Office at the Library of Congress.