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► **To cite this version:**

Michel Fingerhut. The IRCAM Multimedia Library:: A Digital Music Library. IEEE Forum on Research and Technology Advances in Digital Libraries, May 1999, Baltimore, États-Unis. hal-01156506

**HAL Id: hal-01156506**

**<https://hal.science/hal-01156506>**

Submitted on 27 May 2015

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# The IRCAM Multimedia Library: a Digital Music Library

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*IEEE Forum on Research and Technology Advances in Digital Libraries (IEEE ADL'99), Baltimore, MD (USA), May 19-21, 1999*

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[The slide presentation of this article is available online at  
<[URL:http://mediatheque.ircam.fr/articles/textes/Fingerhut99b/](http://mediatheque.ircam.fr/articles/textes/Fingerhut99b/)>.]

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## Abstract

*This paper describes the transition of the IRCAM Music Library from a traditional setup to one tightly integrating digital technologies: online collections of self-describing multimedia objects, networked access and delivery on LANs and WANs, search tools and interfaces. The goal of this one-year project had been to bring together heterogeneous collections of documents (books, scores, periodicals, commercial and unpublished music recordings, videos...) allowing for their combined use by library patrons on- and off-site, with due consideration for the intellectual property rights of each individual document. The successful integration of these collections has increased public use of the library and influenced scholar writing of musical analyses and the production of musical educational tools. While part of its collections are on paper and will remain so due to technical and legal considerations, other collections are available only in digitized form, with computer search tools and networked delivery.*

## 1. Introduction

The Ircam Multimedia Library provides an online integrated networked access to collections of texts, audio recordings, still photos, films, CD-ROMs, databases and Internet resources, complementing an onsite collection of books, periodicals and scores (on paper).

The simple and structured interface provides search and delivery tools regardless of the document support, eliminating the need to handle different devices (such as compact disc players and VCRs). It is available both on the library local-area network and on the Internet (at the URL <http://mediatheque.ircam.fr/>), with controls preserving copyrights where appropriate.

Its infrastructure combines technological innovation, existing standards and off-the-shelf hardware. It was put in place within a year by a small in-house staff, and opened to the public in June 1996.

This paper describes the development and salient features of this digital music library.

### 1.1. IRCAM and its previous library

IRCAM ("Institut de recherche et coordination acoustique/musique", in French) is a not-for-profit institute for contemporary music. Established in the late 70s by conductor and composer Pierre Boulez and under the current direction of Laurent Bayle, its activities consist of:

- research and development in acoustics, digital signal processing, music perception, computer-aided

composition and related domains;

- hosting guest composers commissioned to write electroacoustical works, and organizing concerts for its yearly musical season;
- organization of colloquia, conferences, short- and long-term educational programs in computer music technologies, music composition and musicology, including degree-granting tracks;
- publication of books, periodicals and recordings on technological and musical topics, reflecting the Institute's scientific and musical production.

A music library had been in existence for years serving mainly the IRCAM staff and professional public (scientists, composers, musicologist and students). Its collections consisted mostly of books, periodicals and music scores on contemporary music and related technologies (acoustics, digital signal processing, perceptionÂ...), as well as in neighboring fields (arts and literature, philosophy, aesthetics, linguistics, ethnologyÂ...) and pre-1945 music belonging to the CNRS ("Centre national de la recherche scientifique", in French) and hosted in the library as part of a joint research project.

These collections did not include the IRCAM recordings of its own concerts and conferences: while the Institute could tape the events and preserve them, it didn't have the rights to access these recordings.

A couple of networked PCs, not connected to the main IRCAM intranet (itself put in place in the early 80s), hosted a proprietary catalogue of the collections. In the early 90s, a locally-written OPAC was made available on the Internet (via telnet, then later via the Web). It was thus probably one of the first music libraries on the net.

## **1.2. The IRCAM project**

In the mid 90s, a major rehabilitation architectural project was launched. Its goal was to provide IRCAM with much needed extra floor space to host its growing activities and extend its library's public space and allowing its opening to outside patrons.

In 1995, it was decided not only to transfer the library to the new facilities, but also to transform it into a multimedia library by expanding the existing collections with the IRCAM audio recordings (after having obtained the rights to open them to the public), a collection of documentary movies on contemporary music and a database of contemporary composers and their works. It would use the networking and audio technological know-how of IRCAM in order to present a modern and integrated access to this new collection, geared both to its musical and scientific staff as well as to the public at large.

## **1.3. Related projects and other resources**

During the design period, the Internet was used as the principal information resource. Several library- and digital library-related mailing lists (BIBLIO-FR, PACS-L, PACS-P, WEB4LIB, GO4LIB) provided direct access to a large number of experts in various domains corresponding to specific aspects of the project. This was particularly helpful in selecting the library software systems that were evaluated in the course of the project.

Many Web sites were providing insights in the emerging domain of digital libraries. As the editor and sole writer of the quasi-weekly technological newswatch newsletter *L'Oeil du SystÃme* [17] this author had collected much information on such resources, among which the *D-lib Program* [10] and its magazine, a monthly compilation of contributed stories, commentary, and briefings, deserve special mention for their quality, breadth and depth of information.

Several existing projects were looked at. While none providing a fully integrated CD quality multimedia system as the one IRCAM aimed for, they supplied useful ideas. The multimedia catalog of the

Bibliothèque de Valenciennes (France) [20], a large project which opened to the public in 1995, implementing a system which allows the user to handle bibliographic records, images, average-grade sound and audiovisual excerpts, and CD-ROMs through a unified system in a traditional library over an ATM local network, with a proprietary OPAC. The technologies were developed by Archimed, a French multimedia company.

The Archivo General de Indias in Seville (Spain) [21], inaugurated in 1992, implements an online catalog of a vast collection of manuscripts, and to many (eleven million) scanned images of the manuscripts themselves. While the design and implementation were proprietary, this exemplary integration of catalog and material was instrumental in deciding upon such a connection between records and data in the future system.

Finally, the Variations Project in the Simon Music Library and Recital Center at Indiana University Bloomington [9], which provides access to thousands of titles of near CD-quality digital audio to users at computer workstations encouraged this team to look at streamed compressed audio over a network as part of the design. Fruitful email discussions with David E. Fenske, head of the Music Library, provided valuable insight in their particular use of this technology.

## 2. Technical description

The following paragraphs describe the design goals of the new library and the resulting implementation.

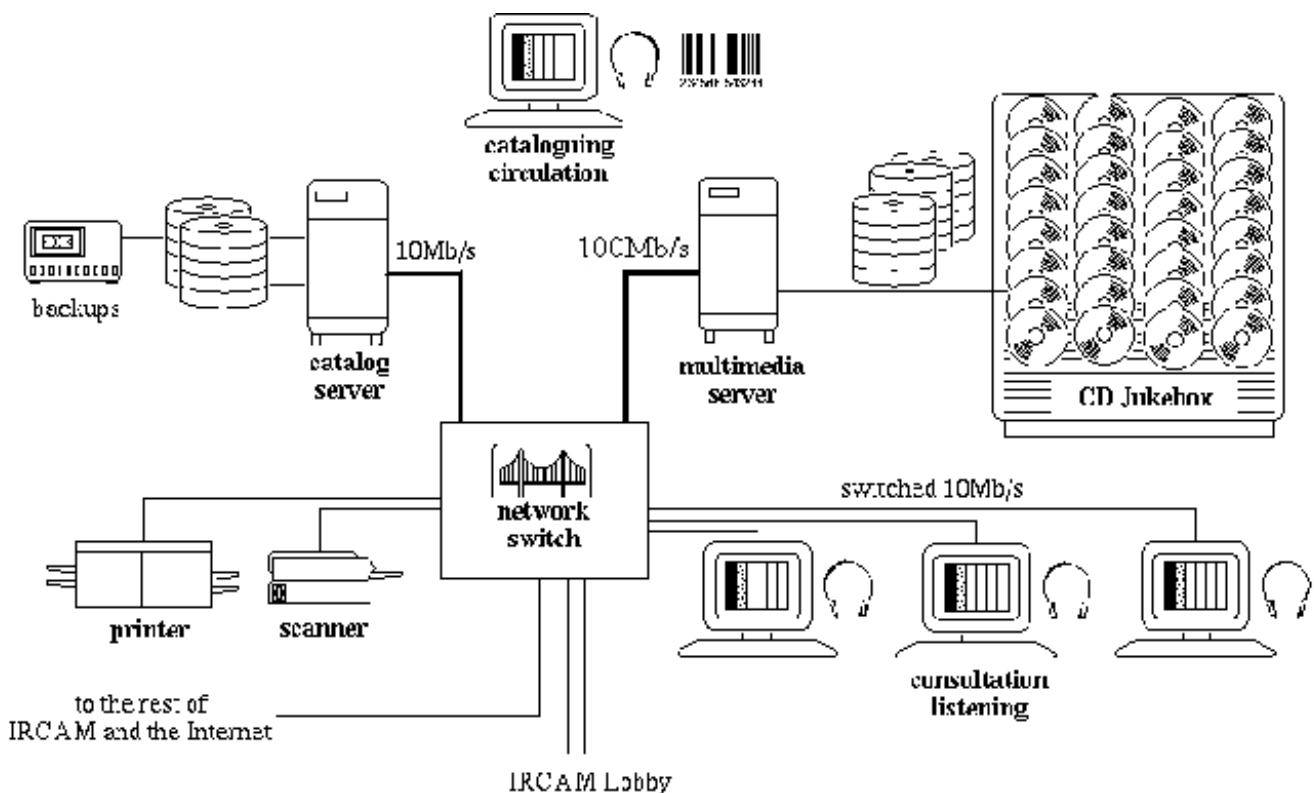


Figure 1. The network architecture

### 2.1. Design goals and constraints

Since time and budget constraints were stringent (one year from inception to opening to the public), the project had to reuse as much as possible existing infrastructure (in this case: the proprietary catalog), technologies and standards, when available.

**2.1.1. General architecture.** A client-server paradigm was chosen (see figure 1). The server would store the catalog and digitized collections. At the patron terminals, HTML (Hypertext Markup Language, used

to design Web pages) would be the sole interface to the system, as an open, non-proprietary and extensible environment allowing for the interfacing to, and correlation of, databases, text, audio and video. This choice was also made so as to provide remote access to the online library through publicly-available tools (i.e., Web browsers).

**2.1.2. Choice of collections to be digitized.** An important part of the first phase of the project consisted of assessing which of the media in the library's collections could be accessed solely through such a network of computers.

Books and scores were excluded at the outset: the collections comprise mostly recent material protected by copyrights and thus prohibitively expensive (except for IRCAM publications). Available computer screens, graphic boards and central units were not (and still aren't) of adequate quality (size, resolution, display speed) to allow for the presentation of scores in a usable fashion: size of the page (sometimes up to A3 with minute inscriptions) which has to be viewed all at once (no scrolling), instantaneous display of individual page and transitions from page to page when reading it while the music plays.

IRCAM's scientific and musicological articles published in its own books and periodicals or elsewhere would be collected, digitized and made available with "interesting" search tools, such as full-text search and retrieval.

The audio documents were good candidates for such dematerialization. These were of two sources:

- The IRCAM concert collections: recorded since the late 70s on analog tapes, they would have to be digitized in a predetermined format. A *sine qua non* requirement from the SPEDIDAM (Soci t  de perception et de distribution des droits des artistes-interpr tes de la musique et de la danse), representing the rights' owners, was that patrons would not be able to handle the physical medium (compact disc, hard disk, tape or whatever) nor record their contents, all the more so since these documents are generally unique and not commercially available.
- Commercial CDs: they would have to be made available in the same "dematerialized" way - i.e., no manual access - yet without copying them on hard disks (for copyright reasons).

Regardless of the means to store the audio documents, the delivered sound had to be of CD-quality, in a quiet environment (computers' central units are usually noisy).

Videos could also be presented on the computer screens with the same constraints; this would require negotiating digitization rights. As to the CD-ROMs, the added dimension of interacting with them through a network had to be solved.

**2.1.3. Interface design.** The interface would have to provide the means to correlate text, audio or video by contents (e.g.: a biography of a composer, recordings and filmed performances of his works), and provide a seamless transition from one to the other. At the same time, this interface should present different cross-sections and access means to the collections: e.g., "all the videos" (regardless of their relationships with other material).

All the multimedia documents would be either catalogued or referenced through the catalog: a record for a score by a given composer would not only provide the call number for the paper document, but also links to the online biography of the composer and to musicological notes about this work and online recordings and videos (see figure 5 below).

While computers are increasingly omnipresent, non-technical people may not be familiar with them, and even be reluctant to use them. They thus had to be as invisible as possible, providing an easily-understandable and simplified interface - much simpler even than, say, currently available Web browsers with their ever-growing number of menus and controls.

This interface would have to provide intuitive controls for the multimedia material, as close in representation as possible to the actual devices most people use at home for compact discs and video-tapes.

This system would be part of the IRCAM local-area network, which is in turn directly connected to the Internet: library patrons would thus be able to reach outside sites on the same terminals, while Internet users at large would be able to access some of the library online resources. A strict policy of security would have to be implemented, so as to restrict or prevent undue access to copyright documents (such as, but not limited to, audio recordings and video films) and to other parts of the Ircam network. Access from within the library to the Internet would also be limited to sites in related domains of interest.

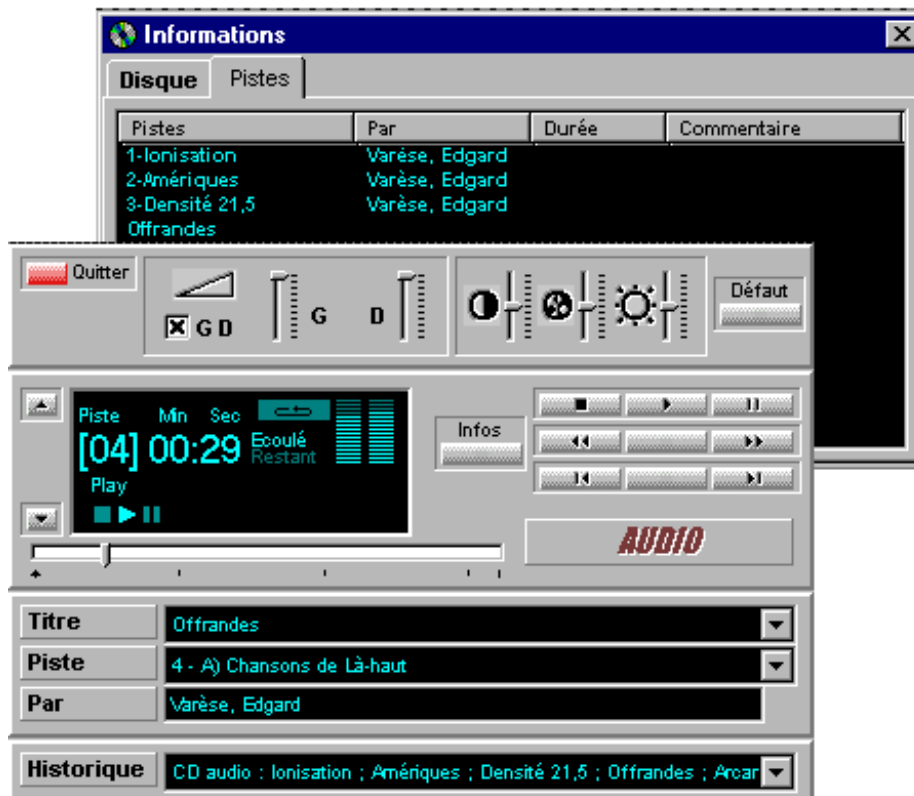


Figure 2. The audio player

## 2.2. The standards

The standards and technologies that were selected in order to fulfill the above requirements are summarized in the following table:

Table 1. Selected standards

General interface	HTML (and Z39.50)
Catalogue records	UNIMARC
IRCAM sound recordings	MPEG-1 Layer 2 (384 Kb/s)
Commercial CDs	Stereo samples at 44.1KHz (1.4 Mb/s)
Compressed video	MPEG-1 (1.8-2 Mb/s)
Still Images	JPEG (and GIF)
Network protocol (high)	TCP/IP
Network protocol (low)	Switched Ethernet, Fast Ethernet

HTML (version 2.0 at the project start in 1995, then 3.2 [14], and 4.0 now) was the best standard allowing for a rapid design, implementation and modifications of all the screen interfaces, in contrast with proprietary OPACs. It also provided for a seamless integration with the Internet - both for patrons' access to outside resources and opening up most of the site to outside queries. In order to develop a stable and standard interface, it was decided not to use any such extensions as Java or Javascript, which were still in evolution. The only non-standard feature which was adopted then, and which later integrated the language definition, was the subdivision of Web pages into so-called frames (or sub-windows). All pages of the server had to adhere to a unique format.

Z39.50 is a well-established information retrieval protocol allowing for a client machine to search databases on a server machine and retrieve records that are identified as a result of such a search [32]. While such an access to the catalogue was desired, it turned out there was no way to do so within the allowed framework of time and budget. A subset of this protocol, WAIS, was used to implement the full-text search and retrieval (see below).

The UNIMARC standard for description of bibliographical records [19] was selected as the more prevalent one in Europe, with the intention of facilitating the task of importing and exporting records. The existing proprietary catalog would have to be automatically converted (as best as possible) to this standard and imported, so as to avoid recataloguing everything.

The MPEG-1 Layer 2 at 384 Kb/s standard [16] was chosen after a series of perceptual tests which were performed at IRCAM on a sample of compressed audio recordings of electro-acoustical music. This rate proved to provide no perceptually significant loss in quality of delivered audio.

The library being slated to open with 10 multimedia terminals (never to exceed 30), Ethernet could be safely chosen as the transport mechanism, both for the servers and the clients, over a cabling system allowing for future expansion to other, faster protocols if necessary.

### **2.3. The hardware and the network.**

Two distinct servers were selected: one hosting and delivering the non multimedia documents (the catalog, Web pages, still pictures, etc.), and connected to a 10Mb/s Ethernet segment; one for the multimedia documents: sound recordings and videos, digitized, compressed and stored on standard RAID disks, and compact discs and CD-ROMs in specially chosen jukeboxes.

Separate servers, both off-the-shelf microcomputers, were intentionally selected so as to increase reliability: the system would still be able to deliver most of the information should the multimedia server be shut down for maintenance or upgrade (including addition of CDs in the jukeboxes). It would also facilitate setting security barriers to prevent undue access to online multimedia.

The jukeboxes deserve special mention: as described below, their CD readers have to implement a command allowing the host computer to read audio CD contents into its memory through the SCSI bus. This feature is not found on all CD players.

The user terminals are off-the-self personal computers equipped with a professional audio board and an MPEG video board with hardware MPEG decompression), and connected to a 10Mb/s switched Ethernet branch.

An off-the-shelf network switch was selected to distribute the network to all endpoints at the required rates.

### **2.4. The software**

While turnkey solutions were available then and could satisfy most of the requirements, they were way too expensive. It was thus decided that the system would be built out of existing, separate, functional blocks, and adapted and integrated by the project team to fit the requirements. Most of the specific developments had to do with streamed multimedia.

Table 2 below summarizes the principal software components that were selected in this implementation.

**Table 2. Software components**

<b>Server Software</b>	
Library Software	<i>Loris</i> (Ever)
Web server	<i>Apache</i> (Apache Group)
Multimedia server	<i>CDLine</i> (Archimed)
Full-text search	<i>FreeWAIS-sf</i> and <i>Sfgate</i>
<b>Client Software</b>	
Web browser	<i>AIE</i> (Archimed)
Multimedia viewers	Archimed
<b>Utilities and Languages</b>	
Audio extraction	<i>Disk-to-disk</i> (Microtest)
Audio compression	<i>Logiciel de codage MPEG 1 &amp; 2</i> (CCETT)
Underlying language	<i>Perl</i>

*Loris* is a commercially available integrated library system developed by Ever, a French company specializing in information systems [18]. It offers a collection of modules for cataloguing in UNIMARC, performing standard library tasks (circulation, acquisitions, serials...) and was among the few such systems to have a Web interface for retrieval. It was also supposed to provide a Z39.50 interface, but this didn't happen.

The price of *Loris*' optional full-text search module precluding its use, the freely available *freeWais-sf* [25] and the *SFgate* WAIS-to-Web gateway [23] were chosen instead, both distributed in source code allowing for an easy tailoring to the project's needs. The first of these packages is an extension of the *freeWAIS* software provided by the Clearinghouse for Networked Information Discovery and Retrieval (CNIDR). The SF suffix in the software name stands for "structured fields," a feature which allows for indexation and search in distinct fields of a structured document, such as author, title, body, etc. The WAIS (Wide Area Information Servers) protocol is based on Z39.50-1988.

*Apache* is a freely available robust, commercial-grade, featureful, and freely-available source code implementation of an HTTP (Web) server, developed and distributed by the Apache Group [3]. It is probably the most prevalent Web server on the Internet. Among its useful features is the ability to control the contents of Web pages as a function of the Internet address of the accessing browser, thereby allowing for the implementation of all necessary intellectual property rights controls.

Archimed's *CDLine* server [4] which was originally designed to stream audio and video data from hard disks on a server and CD-ROMs either from CD towers or hard disks was extended according to IRCAM's specifications so as to stream audio from standard compact discs and serve CD-ROMs, both from jukeboxes connected to the server via a SCSI bus. The client interface (see screen shots in figures 2-4) was designed so as to display realistic-looking CD players and VCRs, yet with detailed track information for records. Archimed also provided *AIE* (Archimed Internet Explorer, based on Microsoft's Internet Explorer)



according to IRCAM's specifications, as a simple and secure Web browser (see below).

IRCAM own recordings were available on locally-pressed hybrid CDs (see below). Their audio contents had to be extracted, then compressed to the selected MPEG standard with two specific pieces of software:

- *Disk-to-disk for Windows and Mac* by Microtest (an american company based in Arizona), the only software to be found then which managed to extract audio tracks from compact discs through a SCSI bus to a local disk without loss of information.
- *Logiciel de codage ISO MPEG 1 et 2 Layer II* by the CCETT (Centre Commun d'Études de Télédiffusion et Télécommunications, a research center of the France Télécom group and important actor in the MPEG standards group), which proved to be the only available algorithm correctly compressing electro-acoustical audio data without producing any singularities in the resulting file.

Finally, most of the underlying programs performing such tasks as database lookups, on-the-fly formatting of Web pages and the like, as well as offline utilities, were written in Perl, a freely available commercially-supported cross-platform scripting language and a GUI programming environment, allowing for very rapid development through its powerful pattern matching primitives [29].



Figure 3. Popup history window (all multimedia)

### 3. Principal characteristics and innovations

The architecture of this system, as built from mostly off-the-shelf components, is innovative in its integration of multimedia in a library environment, preserving its traditional paradigms. The following paragraphs describe the various novel aspects of the project.

#### 3.1. Resource description and referencing

Since the concept of metadata as the description of information objects to support the searching, assessment and acquisition of information available in digital libraries [6] was barely emerging then, the project had to develop its own concepts for describing its digital objects (audio and video in addition to the "traditional" text material of a digital library) and accessing them, within the framework it had chosen to use (i.e., HTML). Two interesting ideas emerged: self-describing objects (the "metadata" is included in the

object itself, much as in object-oriented languages), and referencing object parts (e.g., tracks or movements in a recording, a scene in a video) through standard URL techniques.

**3.1.1. Self-describing compact discs.** The IRCAM concert recordings were transferred to self-describing hybrid compact disc, whose first track is a text file describing, in a structured and detailed fashion, the contents of the recording. Each subsequent track on this compact disc is an audio track (which can be listened in a regular compact disc player) containing the recorded event(s).

These records are then inserted in a free slot in one of the jukeboxes, or copied onto the RAID disks. Either way, their description is available to the online databases and search and display tools, and allow for the detailed display of their contents when listened to (see figure 2).

This process could not be applied to commercially available compact discs, since they don't contain a unique code that would allow for their automatic referencing in a database, in spite of some existing efforts; CDDB [24], barely in its inception then, was (and is) not a standard, does not identify records in an absolute unambiguous way and does not provide for structured description of their contents. More recently, an "International Standard Recording Code" (ISRC, [15]) has been proposed as a means for identifying sound and music video recordings down to single tracks, and some CD players were advertised as "CD-Text Ready", using the CD-Text data embedded in the P-W subcode channels to display disc and track title data [8]. Neither of these proposed standards was available or in wide use then.

Instead, a format for description of music works for audio CDs was developed, which took into consideration not only their physical structure (tracks) but their possible regrouping in hierarchical musical structures (musical movements). This information is stored in a database on the server which delivers the audio, allowing the interface to display it much as for an IRCAM hybrid disc.

As for the patron, both types of media are referenced and displayed identically.

**3.1.2. Self-describing texts.** All musical and scientific texts that are digitized and made available contain their own description (author, title, publishing information). At the time the mechanism was developed, the HTML META tag didn't exist, so HTML comments were used instead. The *FreeWALS-sf* full-text indexing software was parametrized to recognize these tags and create appropriate indexes, providing thus the ability to search, via Web forms, for documents matching any combination of criteria specified for these fields.

**3.1.3. UNIMARC referencing of online documents.** The 626 field of the UNIMARC record ("Technical Details Access (Computer Files) (provisional) (repeatable)") was selected to store the URL (network electronic address) of any document, provided it is available online. This applies to texts, videos, compact discs (in jukeboxes or on a hard disk) and CD-ROMs. The screen view of their record contains an icon (indicating the document type: text, audio, video...) next to the title, allowing one to view, or listen to, the required document directly from its bibliographical record by clicking on that icon (see figure 5).

In 1995, this was indeed the more appropriate record for such purposes. More recent versions of the UNIMARC standard [30] have defined the 856 field as "Electronic Location and Access (Repeatable)" to provide for this use. A conversion from the 626 field to this one will probably be effected at a later time, in conjunction with a general upgrade of the library software system.

The same mechanism is used to link bibliographical records of scores to an online musicological text about the work (see figure 5). An electronic link in the authority records for authors (=composers, in this case) leads to the biography of that person, if available online.

**3.1.4. UNIMARC cataloguing of music scores instrumentation.** A set of fields (within the 9-- block) was used for the specification of detailed instrumentation of scores (see figure 5), thereby allowing patrons to search for musical works according to a desired instrumentation [7]. The contents of these fields (structures, codes) were established in conjunction with other music institutions and will be presented to

standards organizations.

**3.1.5. URL referencing of multimedia objects and their parts.** Specific MIME (Multipurpose Internet Mail Extensions) types were defined for the two kinds of streamed audio (compressed on the RAID disks and stored in the jukeboxes), videos (compressed on the RAID disks) and CD-ROMs (stored in the jukeboxes). This allows for the use of URLs in hypertextual documents in order to launch the local viewers monitoring the playback.

A particular extension of the URL syntax was used to allow for addressing a single track on a compact disc (using the # character, the so-called *fragment identifier*, as defined for text documents), and a range of tracks and/or parts of tracks (specified as time offsets within the track). It is thus possible to refer, in a Web page, to a piece of music recorded on part of a compact disc by specifying a hypertext link that, when selected, will launch the CD player at the track where the piece starts, or within the track at a particular phrase, say. This syntax may be used with a similar effect on digitized video documents.

This interpretation of the fragment identifier could also be used to access parts (i.e., subrectangles) of still pictures, but this project didn't require such a feature.

## 3.2. Content delivery

All online documents (text, audio, video...) are delivered to the user via a single, computer, network, regardless of its storage support (jukebox, hard disk) and format (compressed or not). The servers ensure that the intellectual property rights are preserved, and do not deliver documents or parts thereof to unauthorized parties.

**3.2.1. Streaming compact discs on Ethernet.** One of the main technical innovations of this system is the online delivery of audio from the actual compact discs through a computer network (rather than through a switched audio network) to the client terminal, the records being stored in jukeboxes connected through a SCSI bus to the server.

This was made possible by a careful selection of devices comprising CD players with the *read CD-DA* command [13], which allows for reading the contents of the audio tracks directly into the host computer. By accessing this information much faster than at a regular CD rate, the server can then transfer the samples it read "at leisure" to the terminal requesting this compact disc, through a particular client-server protocol developed over TCP/IP. A switched Ethernet connection of 10Mb/s per client terminal is adequate for this type of one-way stream of ca. 1,4 Mb/s.

The server is connected to a 100 Mb/s Fast Ethernet segment, which allows for serving the existing 10 multimedia clients without any problem. It is likely that over 30 terminals could be used with this particular setup.

An interesting byproduct of this use of networked audio compact discs is the surprising fact that a single compact disc can be used simultaneously by several people listening to different parts, much in the way a hard disk is transparently shared by many users, the actual number of listeners depending on the speed of the CD player and the time needed to reposition its head.



Figure 4. Video player

**3.2.2. Controlled access to documents at the component level.** Among the salient features of the Apache Web server, its *extended server-side includes* allows for the implementation of a strict policy of access to parts of text documents depending on the client's location: if within the library, the whole document displays on his screen; if elsewhere, only parts of the documents would show up, such as the abstract, the other parts (e.g., photos, copyright text) not being included in the HTML page sent back to the client, as dynamically built by the Apache server.

### 3.3. Interfaces

Many innovations had to do with the interfaces. While the use of new technology was a given, it was the intent to provide light tools to the visitors and simple choices as to their preferred ways to access data (browsing or searching), using intuitive and familiar interfaces, rather than overwhelm them with technology and impose a single view of the collections.

**3.3.1. Simple and secure terminal.** As mentioned above, the browser was developed by Archimed according to detailed specifications and based on Microsoft's *Internet Explorer*. As a beta tester for Mosaic (the first widely distributed Web browser), this author had had ample experience in testing and helping specify its so-called "kiosk mode" (reduced functionality for secure use in a public terminal environment) on the computers of the Pompidou Center's Bibliothèque publique d'information (BPI). Neither Netscape nor Microsoft's Internet Explorer provided anything close to this level of security. These are some of its principal characteristics:

- The browser takes over the whole screen and does not let the user to escape to the underlying system by whatever means (control keys, mouse menus...). The terminal (a PC) thus becomes a so-called network computer.
- All standard menus of the browser are suppressed, to leave only 4 controls: *forward*, *backward*, *redraw* and *stop*. This significantly simplifies its use for non technical people. Other configurable menus are available, leading directly into the main sections of the Web server.

- The browser is configured to allow only access to selected URLs (as specified with a regular expression syntax, controlling both the protocols - such as http, telnet, ftp... - and the addresses) in a configuration file. This prevents uncontrolled access to the Internet and to its protocols from the public terminals. In effect, the access is limited to a (large) collection of related sites listed in various parts of the server.

Further security is ensured at the client's PC terminal by removing the central unit away from the screen, keyboard and mouse, using commercially available extension cables and by locking them in a specially cooled and insulated locked cabinet. This achieved two benefits:

- Preventing access to the central unit (initialization, reboots, floppy disk insertion and removal, etc.).
- Providing for a quieter environment in the reading room: central units usually contain cooling fans, whose noise adds up when several such units are close by.

**3.3.2. Uniform site and page layout.** In order to facilitate the navigation through the site, all its sections are presented in the same fashion on the screen, using the same layout of frames, as defined by a single file common to all the server's directories.

Similarly, all individual frames are laid out according to a strict policy. As a result of this choice, all the digitized texts coming for various IRCAM and other publications have to go through a process of reorganization so as to fit this policy.

**3.3.3. Improved interface to audio and video documents.** While many of the more popular computer media players display the individual track identification when playing a virtual compact disc, there was none to be found which allowed for the display of a group of tracks as a single work. IRCAM's request from Archimed in the implementation of the audio server (where all the tracks of each compact disc are referenced) and of the virtual CD player was that they would allow for the regrouping of adjacent tracks under a single heading.

Both the audio and video players provide all the familiar controls available on their physical counterparts. The video player allows for full- or 1/4 screen display. The use of a player which is not integrated in the Web page allows for the simultaneous listening of audio, say, and reading of related online documents.

Through a popup history window in both players (see figure 3) the listener can directly access a previous multimedia document of any kind (audio, video or CD-ROM).



**3.3.4. Alternative means of access to the catalog.** While the catalog may be accessed through a so-called form query page, allowing the patron to fill in one or more boxes specifying author, title, collection, etc., several other means of access were provided:

- access by classification scheme: the call number of the documents is composed of a 3-digit prefix, each digit corresponding to a class of documents, the next digit to the right to a corresponding subclass. A Web page allows one to browse each category and select any of its existing subcategories. When the 3rd level has been selected, the catalog is called to display all corresponding documents.
- access by floor plan: a "clickable" 2D map of the library allows the patron to select any shelf or cabinet and display its contents. The initial idea for this access was influenced by the interface of the Informatics Library at the Oslo University [26] and to fruitful email discussions with Knut Hegna.
- from bibliographical record to floor plan: the screen view of catalog records contains a floor plan of the library, highlighting the cabinet or shelf on which the actual document can be found. All the other shelves and cabinets can be queried too, as mentioned above.
- virtual reality interface: a VRML [31] model of the library has been built, allowing the user to move (virtually) in the library and click on the cabinets and shelves to have their contents displayed (see figure

6).

All these interfaces are available from any Internet site.

**3.3.5. Other innovative interfaces.** Experiments with RealNetworks' Synchronized Multimedia Integration Language (SMIL) [5] led to the production of an online playback of a recording with a synchronized presentation of its score (the chosen piece was Cathy Berberian's *Stripsody*). The audio streams using RealNetworks' RealAudio technology, and the images are either GIF or JPEG. While the sound quality is adequate for Internet streaming, it nowhere matches that of the actual recording provided through direct access to the compact disc, and it cannot be applied either to pieces with larger scores, due to the severe limitations of the computer screen (as mentioned above) and of the RealNetworks G2 player. However, this proved to be an interesting technology to use in IRCAM's in-house online documentation of musical works and musicological texts [1], taking advantage of available online musical material which can be referenced inline where pertinent.

	<b>Auteur principal</b>	<a href="#">AMY, Gilbert. (1936)</a>
	<b>Titre</b>	Echos XIII, pour cor, trombone, harpe, piano et neuf instruments
	<b>Responsabilite</b>	Gilbert Amy
	<b>Aut.Editeur</b>	<a href="#">Universal Edition</a>
	<b>Lieu pub.</b>	Londres
	<b>Date pub.</b>	1977
	<b>Editeur</b>	Universal Edition
	<b>Descr.</b>	1 partition (39 p.)
	<b>Note</b>	Cotage : UE 16672 LW
	<b>Date de composition</b>	1976
	<b>Durée</b>	14 minutes
	<b>Commanditaire</b>	Commandée par la Fondation Koussevitsky
	<b>Dédicataire</b>	A la mémoire de Nathalie et Serge Koussevitsky
	<b>Instruments solistes</b>	1 cor, 1 trombone, 1 harpe, 1 piano
	<b>Bois</b>	2 flûte, 1 clarinette, 1 clarinette basse, 1 basson (La flûte prend aussi la flûte piccolo)
	<b>Cordes frottées</b>	1 violon, 1 alto
	<b>Cordes frottées</b>	violoncelle1
	<b>Cordes frottées</b>	1 contrebasse
	<b>Date de la création</b>	Novembre 1976
	<b>Interp. de la créa.</b>	Ensemble Musique Vivante, direction: Gilbert Amy
	<b>Lieu de la création</b>	Etats-Unis, pour la tournée américaine de l'Ensemble Musique Vivante

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- Médiathèque - Pm 389 AMY.1 Ech - Partition - Disponible
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**Figure 5. Screen view of a bibliographical record**

The current lack of scientific presentation tools in HTML is a serious handicap for online publication of IRCAM's research articles, many of them including mathematical equations. A recent successful assessment of MathML (Mathematical Markup Language, [28]) provides for a satisfactory solution to this problem.

## 4. Present and future

The system has now been in operation for over two years. In retrospect, it turns out that the design was sound (no performance problems even at maximal use or when adding new features), and the system fairly reliable (very low number of failures and almost no downtime) and easy to use (user satisfaction).

It was not aimed at creating an online library which would replace the real one, an impossible task given the current state of technologies, for one thing, but more importantly a futile one: when all is said and done, reading on paper is easier than reading on screen (computers do not reduce the use of paper - on the contrary).

On the other hand, it extends the functions of the library in ways only computers can: the full-text search in the collection of online papers would have been impossible otherwise, database search is an invaluable tool for scientists and musicologists alike, the seamless integration of the other media such as sound and video allows for a much easier access to collections.

The underlying technologies evolve without much difficulty: the change from FDDI (the initial choice for the 100Mb/s network segment) to Fast Ethernet (when it became available) for the multimedia server was an almost instantaneous operation, as were the upgrades of some of other hardware or software subsystems (e.g., *Apache*).

The choice of HTML as a presentation does not allow for a very rich layout. It lacks, among other things, integrated facilities for equations (MathML is an extension), which are an essential necessity for technical papers, and does not provide for a subtle placement of diagrams and illustrations. Yet it is lighter than, say, Adobe's Portable Document Format (PDF) [2], is a non-proprietary industry standard and allows for a much easier full-text structured indexing with *freeWAIS-sf* and integration with all kinds of present and future multimedia documents, within the Web page (through so-called *plugins*) or with external helper applications.

The *freeWAIS-sf* full-text module provides for the inclusion of customized filters for the indexation of arbitrary types of document. This opens up interesting vistas for the subsequent integration of "intelligent" indexing and retrieval of multimedia documents (e.g., through melody or other significant features).

Looking into the future of HTML, the fact that it is derived from the Standard Generalized Markup Language (SGML) [12] makes its transition towards the emerging Extensible Markup Language (XML) [22], itself a richer subset of SGML, much more likely. XML will include such mathematical extensions as the Mathematical Markup Language [28] or similarly designed languages.

In any case, well-structured HTML pages will in all likelihood port easily to XML. Even the early choice of HTML comments for meta information can be automatically converted to stable, standard tags.

The recent developments of the UNIMARC standard allowing for the integration of electronic addresses of online documents in the 856 field (as mentioned above) will lead us at a later time to switch from the 626 field to the newly established one.

The underlying software and hardware server-client structure will easily adapt to such new media as DVD (Digital Versatile Disk) [6] when it finally becomes a stable standard and interesting documents appear at a reasonable price (mostly for video).

The VRML interface was an experiment in assessing the use of this language for a much more content-oriented project: providing a 3D virtual model of selected domains or concepts of contemporary music, allowing the user to stroll along paths representing people, works, concepts. VRML integrates well with the existing system and its online resources - texts, images, sound and videos (integration of virtual reality and Web material already exist, but for real spaces, e.g. the Virtual Reality Walkthrough down the National Gallery of Ireland [27])

Finally, not to forget cataloguers, whose meticulous task is essential to the well-being of a library: why not wish for a not-too-far future, in which all documents (books, periodicals, records, videos, cdroms...) will include a standard self-descriptive computer-readable record in a MARC or XML format, and incorporated in the document by its publisher?



Figure 6: A VRML view of the library

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As mentioned above, most of the information for the project was found on Web servers on the Internet. Where references do not exist anymore, updated links have been provided. All were checked on December 1998.

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