Studio Online 3.0:
An Internet "Killer Application" for Remote Access to IRCAM Sounds and Processing tools

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Abstract: *Studio Online 3.0 is the final version of an Internet music application with distributed objects developed at IRCAM in 1996/8. This application offers high-quality instrumental sound "online" for music researchers, composers and professional audio studios. Studio Online is 3-tiered: a client applet runs in a standard Web browser and connects to a server hosted at IRCAM providing access to IRCAM sound transformation tools and to a large sound database. The uniqueness of Studio Online lies in its ambition to serve the needs of scientific music research, contemporary composition and pedagogical activity. The overall goal of the project was to provide an efficient and easy-to-use application for contemporary audio research, composition and music production with the exclusive use of non-proprietary software tools and open standards.*

Keywords: World Wide Web, Audio Databases, Sound Processing, Distributed Computing, Client/Server Architectures, CORBA.

1. Introduction

IRCAM is a world renowned institution with specific competencies in acoustics and psychoacoustics of instrumental sound, sound analysis and transformation software, and computer aided composition. As a major center of musical research and production, it has a special mission of archiving/documenting/teaching contemporary musical use of technology. Additional artistic competence is input by visiting composers and musicologists. Besides IRCAMs departments for research and documentation, there is also a large department for music production and pedagogy.

All of these departments are in constant need of high quality sound samples of musical instruments: the research departments need reference material for their various analyses, and the pedagogy needs specific sound samples for their music productions. Until recently, research and production had to laboriously produce their own sound material every time they needed it, as there was no centralized collection of instrumental sound readily available for their work. With Studio Online, high-quality instrumental sound can now be instantly downloaded at any time to the personal computer or workstation on the office desk.

One other problem tackled by Studio Online is the availability of advanced IRCAM sound processing software for the different users in the institute (composers, researchers, engineers, students) who are typically working on different computer hardware platforms (UNIX workstations, Macintoshes and PCs) and with different sound file formats (IRCAM's floating point format, Macintosh AIFF and AIFC, and Microsoft's WAVE format). All these people need a unified, and somewhat more user-friendly access to the power of IRCAM sound processing tools, without dwelling too much on their various versions, platform dependencies, specificities and intricacies of their handling. Not all IRCAM sound processing tools have graphical frontends like SVP, FTS, Diphone or Patchwork do, and these are only available on specific platforms (Audiosculpt, Diphone and Patchwork only on Macintoshes, jMAx only on some UNIXes).

This was probably part of the motivation for IRCAM to respond to a call by the French Ministry of Industry for proposals of a 3-years project on the "Information Highway", in 1996. After successful completion of the project by the end of 1998, IRCAM has at its disposal a versatile service for the various needs of the inhouse staff, visiting composers, and external users (e.g. Forum members). Moreover, Studio Online can be used by any computer connected to the internet. IRCAM technology can therefore be remotely accessed and evaluated from anywhere in the world. Studio Online permits an instantaneous, around-the-clock access to IRCAM sound archiving and processing power, a remotely configurable and controllable personal music studio for music professionals and laymen. Not only is it possible to download sound from the IRCAM database but also to upload own sound files to a private user space and have them treated by IRCAM processing tools. According to the international character of the Internet, Studio Online is entirely bilingual (English and French).

After a first phase of consolidation, the Studio Online Team formed under the management of Guillaume Ballet and comprised developers Rolf Wöhrmann (1997) and Rodolphe Bailly, Riccardo Borghesi and Peter Hoffmann (1998), artistic directors Joshua Fineberg (1997) and Fabien Lévy (1998), sound engineers François Eckert (1997) and Vérène Gribonval (1998), post production engineers Antoine Mercier, Gérard d'Elia (1997), and Cécile Lenoir (1998), and psychoacoustic research assistant Nicolas Misdariis, as well as a couple of interns. One other project, also supervised by Guillaume Ballet and funded by the Ministry of Culture, specifically used Studio Online sounds for a popular Web site of pedagogical vocation called "Web Culture". This site was developed by artistic director Fabrice Guédy and Web designer Guillaume Dimanche and is accessible at http://sol.ircam.fr/instruments/.

2. Aims and Scope of the Project

It may be adequate to recall the ambitions and aims of the Studio Online Project as conceived by the Studio Online Team led by Guillaume Ballet [Ballet 1998]. One important technical ambition was the exclusive use of open standards (HTML, TCP/IP, CGI, CORBA, SQL) and non-proprietary technology (Java and C++ development under UNIX, standard CORBA tools[1], JDBC). An integrated database client/server development system could probably have facilitated the task, but only at the expense of provider dependency, hardware/operating system limitations, or restricted availability by the internet community (additional client software or even hardware etc.)[2] For using Studio Online, there is no dedicated hardware necessary, no encryption involved, no specific client software, no installation of the client, even no version control necessary, and no dependency on a specific carrier or provider. Everybody can connect: all one needs is a working internet connection (some of them are even free of charge!) and an up-to-date internet browser, which is a piece of free and ubiquitous software. Everybody who has a computer can have that.

One important artistic ambition was to cover contemporary aspects of instrumental sound of specific interest for contemporary electroacoustic composers and/or of specific pedagogical interest. For example, in Studio Online, most instruments (except those with a homogeneous timbre like the strings) are sampled in quarter tones. One can interactively search a large systematic collection of wind multiphonics, as well as some more 200 different 20th century playing modes and techniques as exotic as e.g. for woodwinds: "jet whistle", "key clicks", "kiss sounds", "subtones", breathing and singing through the instrument, and for strings such as rubbing with the finger nail, knocking on the instrument's body, pressure bowing, artificial harmonics (strings), to name but a few [Lévy 1998]. Room acoustics are taken into account by providing 6 channels for each sample: 2 near and 2 far stereo microphone pairs as well as a near and an internal (built-in or contact) microphone.

[1]Non-proprietary in the sense that the CORBA environment could be changed without any loss of functionality. The only exception is the "Gatekeeper" proxy server, which is an added product of the Visibroker ORB (see below).

[2]In fact, there was not even a usable Java/CORBA development tool available at the time of the beginning of the project being able to create multi-tiered CORBA applications.

3. The Architecture of Studio Online

Studio Online has been conceived as a 3-tiered internet application. A client applet (the front tier) runs in a Web browser and connects to a powerful server machine at IRCAM. Two server programs (the middle tier) connect the applet to a sound database as well as to a collection of audio processing tools (the back tier). In spite of being a Web application, on a fast machine and with a good Internet connection, Studio Online almost feels like a local program. The previewing and downloading of sounds and other data (even simultaneously) is managed by the browser so that the user can immediately go on working with the interface while the browser manages the retrieval of the data (even of several sources simultaneously) in the background.

For sound transfers, the applet uses the browser's capabilities of handling various multimedia data for previewing (by spawning appropriate helper applications) or downloading to the user's local hard drive for later use. All other communication is handled by an IIOP CORBA connection through a special proxy server, Visibroker's "Gatekeeper", which works around some of the applet's sandbox security restrictions. For example, it permits connecting to a different server interface than from where the applet was loaded, and it holds a callback connection allowing the server to recontact the applet on asynchronous events. (We use the callback feature to notify the user upon arrival of sounds uploaded to IRCAM and to constantly check the liveness of the client applet during the session.) For details, see [Hoffmann 1998].

Studio Online has two main server processes: one server is written in Java and manages all session oriented aspects. Another server is written in C++ and manages the coordination of the various audio transactions like sound transformation, format conversion and downloading. Both servers are of course fully multithreaded and so handle multiple sessions and requests concurrently. The session server works between the client applet and the database containing all informations about user login and preferences and the sound taxinomy of Studio Online. The transaction server works between the client applet and several IRCAM sound processing and format conversion tools as well as a number of other tools for generating archives, checking the user's disk quota, etc.

The CORBA middleware enables a direct communication among objects distributed between the client applet and the two server programs as if it were just one single object-oriented program. The object distribution is not only perfectly transparent to the user but also to some degree to the programmer, a fact which allows much flexibility in design and implementation of a distributed C/S application.

The session server connects to the database via a JDBC bridge. This server program stands between the database and the client applet and provides a convenient functional layer of abstraction to the SQL database communication. The applet, for its part, presents to the user an even more intuitive visual interface for navigation within the sound taxinomy stored in the database. In an iterative, interactive process, the user is invited to incrementally refine his/her choices on a number of aspects of the sound (instrument, playing mode, pitch, etc.) while the interface constantly updates in order to present to the user the number and the aspects of the sounds that are still available. Behind the scenes, every choice of the user in the interface is converted by the applet into a request over the internet to the session server which sends a corresponding SQL query to the database, evaluates the result and returns the information necessary in order to update the applet interface. Thanks to an efficient implementation of the remote querying process, the interactive sound selection game almost feels as if one had to do with a local installation (provided the Internet access is not too bad).

The actual sound data are not stored in the database itself but on a large RAID disk array. It was found that it was easier to handle them on a file system, as no prediction could be obtained at the time of how the database would eventually behave when loaded with hundreds of Gigabyte of data. In addition, we needed direct access to the sounds during development time and, last but not least, the database BLOB primitives were bugged in Oracle 8. So the database only references the sounds by an identification number which is passed by the applet to the transaction server. The transaction server dynamically creates Perl scripts which contain the sequence of command lines for various tools accessing the sound files on the RAID file system and converting them according to the user's preferences concerning the microphone configuration (near-mono, internal, stereo-near, stereo-far and their left and right channels), the preferred sound file format, sampling rate, quantization and the volume compression of the sounds. On sound download by the browser, the Perl scripts generated by the transaction server are executed through a CGI invocation and transparently convert the desired sound "on the fly" according to the user's specification. The user's preferences are configurable at any time and persistent between different sessions.

Studio Online sounds have not been subjected to any audio compression with possible data loss. The main concern was 100% uncompronized sound quality, and we did not want to trade it off against accelerated downloading time. It is also in order to ease access and to avoid dependency on proprietary compression formats.

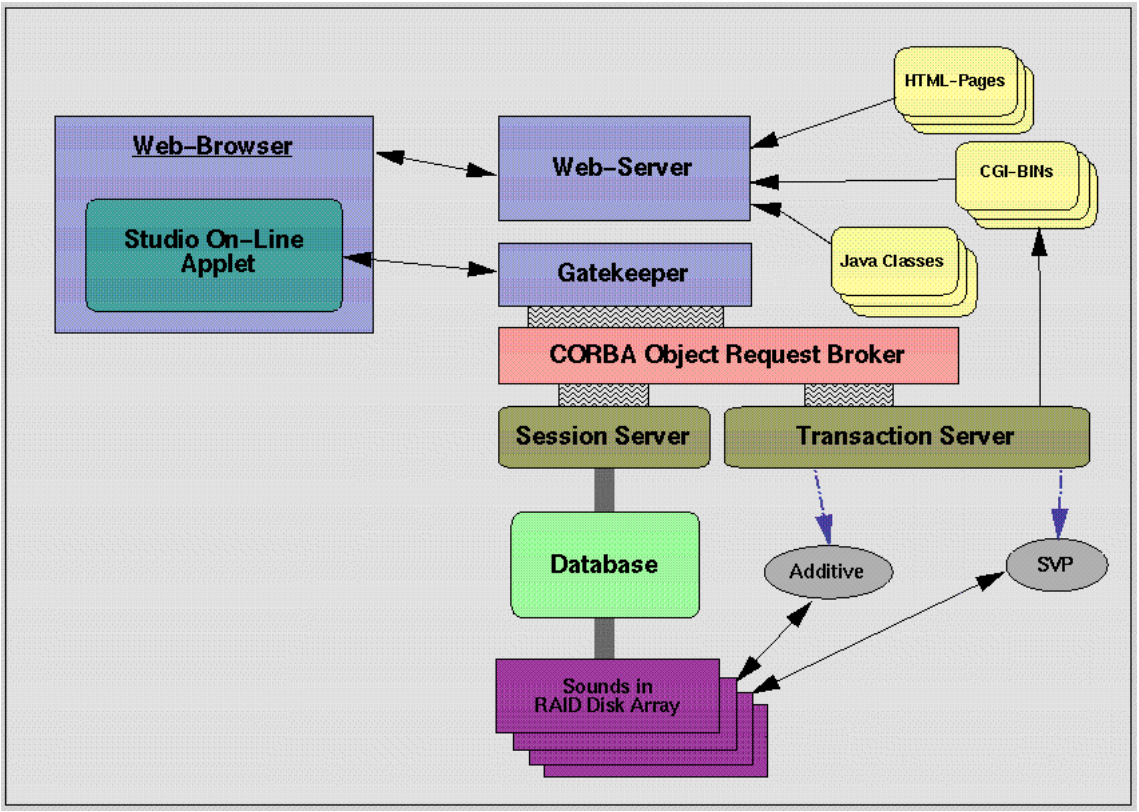

Figure 1: The Studio Online 3 Distributed Architecture

4. Related Work

Other projects have been and are being undertaken around the world to use the Internet as an easy and direct way to access large sound collections. EastWest (www.soundsonline.com) serves 16 bit, 44.1k, WAVE and AIFF sound (over 20,000 instrumental sound samples). Search is done by standard HTML forms on categories and keywords. The sound can be previewed in Real Audio. Download is accelerated by E-magic ZIP compression (30% without data loss) after online payment. However, sound quality is not above standard CD quality. In comparison to Studio Online's 120,000 sounds, the repertoire is limited.

Sound Dogs (www.sounddogs.com) serves over 60,000 sounds and special effects for the cinema (more than 110 GB of data). Search is by categories and keywords, but there is no sound preview yet. Downloading is not interactive at all, for sound is sent by e-mail. The sounds are of a high quality (up to 24 bit, 48k sampling rate) and many different formats are available. These services, however, are not interactive as Studio Online is in the sense that an HTML request is sent and then the user waits for the answer. In Studio Online, client-server interaction is immediate and two-way.

"Studio On Line" (www.audiosoft.com), not to be confounded with Studio Online, serves 16 bit 44.1k sounds and samples for post production studios and professionals. Specific hardware is needed to use this service: a dedicated Client Computer of a specific brand is preconfigured with a Digital Video Broadcast Card, which decrypts audio data from a dedicated satellite connection (Astra Net) in real time. The immediate access (faster than Studio Online, which is not real time) must be paid, in addition to the renting of the service, by proprietary technology and dependency on a specific connection service.

None of the mentioned sites are really musical sites with an artistic vocation but commercial delivery services of some big players in the audio and multimedia market. There are no sound transformations offered as in Studio Online, no interactive navigation on the content of the sound databases or graphical control of parameter configurations as there are in Studio Online like Break Point Functions, compression graphs, and the like, which are only possible through Java programming.

5. A Typical Session With Studio Online

One should not try to connect to Studio Online with an outmoded computer and obsolete browser software. Required is a fast Pentium or comparable processing power, sufficient memory on top of what is already consumed by the operating system and browser software (which is much), Microsoft Explorer 4.01 (build no. 4.72.xxxx.xx) or Netscape Communicator 4.5.

5.1. Startup

On visiting the Studio Online Web page containing the client applet (http://sol.ircam.fr/external/joba) a new browser window opens, the Java Virtual Machine starts up and the compressed Java archive (ca. 3 MB) is loaded. It takes additional time until the classes (a couple of hundreds) are verified by the Java security system and instantiated. This can take a while, and both Netscape and Explorer do not really indicate the progress of this procedure, so one must be patient. (Netscape seems almost frozen during this period, while with Explorer one can easily go on surfing in another browser window.) If the user has configured a sufficiently large Browser cache (10 MB, say) to keep all the loaded Java classes on the local machine, the applet will start up within seconds the next time. This is because the browser then just checks if the local classes are up to date and if so, verification and download of code is skipped.

5.2. Selecting Sounds

The applet first presents the user a login screen where he/she can type a user name and a password. (On a first visit, the user just enters a user name and a password of his/her own choice in order to identify him/herself on later logins.) On pressing the login button, the applet instantiates the ORB classes, connects to the IRCAM server and opens a session. The user preferences of the last session are retrieved (default is AIFF/16 bit/44.1 kHz as sound format and English as language). The user is first presented with a "sound selector" screen which actually is a graphical frontend to the database containing the sound taxinomy. The user selects the attributes of the desired sounds among a number of categories (instrument, playing mode, dynamic, pitch(es), octave(s), channel configuration, etc.) and sees how the selector interface updates in order to show the choices that remain, until the number of hits is reduced to less than or equal to 24 sounds (e.g. a quarter tone octave).

5.3. Managing Sounds: Downloading, Uploading, and Transforming

The user can then load the set of these sounds into the "sound manager". This is a directory view on the user's workspace and the central part of the application. From here the user can transform selected sounds and recursively create subdirectories containing the results of these transformations (which we call "productions": the resulting sound file(s), some analysis files, the parameters of the transformation and a log file). The directory structure thus reflects the transformation "history" of an original sound. The transformation result is automatically previewed by the audio helper application the user has configured in the browser's preferences as soon as the transformation is done.

An interesting chain of transformations, for example, is to split off the noise part of a noisy instrumental sound (e.g. a sul ponticello on a double bass or a flutter tongue on a trombone) with additive resynthesis, to transpose it two octaves higher and to time stretch it by a factor of four. The result is a most interesting sound which has lost almost all similarity to an instrumental sound, while it still benefits from the complexity and richness of a natural acoustic phenomenon. The user can also be interested in downloading the spectral analysis data, and use them on his/her own computer by displaying them graphically with standard software or even inputting them into his/her own software.

The user can upload his/her own sounds up to 20 MB per file to a private directory on the IRCAM server. WAVE, AIFF, AIFC (uncompressed) and IRCAM floating point/short sample sound file formats are recognized. These sounds can be transformed in the same way as the database sounds and downloaded

again, or left on the server for the next session with Studio Online. Up to 300 MB of disk space can be claimed by the user. The transformation results are stored on the server in IRCAM floating point format in order to preserve a maximum of sound quality, so this quota might be reached after some transformations of lengthy sound files. In this case, the user is invited to delete some unwanted results before he/she can proceed producing new sound data or uploading more sounds.

5.4. Configuring User Preferences: Language, Sound File Format, and Compression of Sound Dynamics

At any time, the user can reconfigure his/her preferences in order to adapt to his/her specific local environment (typically PC/MAC/UNIX), linguistic background (English or French speaking), and audio system (does it support Studio Online's extreme 24 bit dynamic resolution?). Pianissimo sounds from Studio Online can be extremely weak when played back on a 16 bit audio system, so we devised a graphical static compressor which permits to directly define a compression curve (linear compression and an optional constant offset) to adapt 24 bit dynamics (about 144 dB) to, say, the 16 bit range (about 96 dB). All of these configurations are immediately taken into account. For example, as soon as the user switches e.g. from English to French, the configuration interface itself becomes French at once (with all accents, of course), as does the rest of the client applet. The same holds for sound transactions: if the user changes from AIFF to WAVE, the next sound downloaded comes as WAVE with Mime Type "audio/wav", and spawns the corresponding application configured in the browser's preferences.

5.5. Search by Psychoacoustic Similarity

This interface complements the systematic choice of the sound selector interface. It is a very powerful search engine through the whole database, across instruments, playing modes, pitches, etc. by preprocessed comparison of spectrally analyzed content only. Surprising results can be obtained and sounds detected that one would not have found by looking up the sound taxinomy [Hoffmann/Misdariis 1998].

This interface has been made much more intuitively by the introduction of evocative terms and the concentration on 3 major perceptual categories of sound: brilliance, richness, and attack. Additional constraints can be requested by the user on spectral energy and/or pitch, restricting the hits to a certain distance in these parameters, and a distinction between percussive and non-percussive sounds can be enforced. Up to 50 found sounds can be compared to the original sound and added to the sound manager for further treatment.

6. Technical Data of Studio Online 3.0

Studio Online 3.0 is what could be called an "Internet Killer Application" [Orfali/Harkey 1998]. It makes use of the latest achievements in distributed computing to connect Internet clients to a sound server and to provide a sophisticated graphical user interface for the remote query process, the sound transformations, the remote managing of the sound files, and the retrieval of the sound data. After trying standard Internet technology like HTML pages and CGI scripts, it was found that only a distributed Client/Server architecture could satisfactorily respond to the needs of interactively navigating in a large sound taxinomy, providing a session oriented workspace, supporting intuitive graphical controls and diagrams, and allowing the user to configure his/her own persistent preferences of sound format, language, compression level, etc. [cf., e.g. Weisbecker/Bauer 1998].

The version of Java used is Java 1.1.3, with the JFC/Swing 1.03 layer on the client side. The ORB software used is Visibroker for Java 3.2 and Visibroker for C++ 3.1. The database used is the Oracle 8.0.3.0 database accessed by JDBC 8.0.4.0.6 Level 2 drivers.

The Web server is Apache 1.2.4, and the dynamical sound conversion scripts are launched by CGI calls with Perl 5.0.3. The conversion programs are IRCAM's STtools toolkit (updated and completed by the Studio Online Team).

The server machine is a Sun Microsystems Enterprise UltraSparc 3000 running Solaris 2.5.1.

The disk array is a Sun Microsystems Raid RSM 2000, configured Raid 5, with 31 disks à 9 GB each, plus two hot spare and a cold spare disk. This gives us, after formatting, a usable disk space of 190 GB. The database disk (1 HD)is fully mirrored with RAID 0+1.

The sound total is 113.823 sounds with 6 tracks each, sampled with 48k, 24 bit (ca. 130 GB of data, which correspond ca. 12 days of continuous listening).

7. New Features in Studio Online 3.0

During 1997, brilliant developer Rolf Wöhrmann created, in close collaboration with Guillaume Ballet, versions 1 through 2.6, gradually fixing the architecture as described above [Wöhrmann 1997, 1999]. This version was a fully working, albeit somewhat restricted prototype which already served the needs of a constantly growing user group. During 1998, the sound database was completed to 16 instruments by the recording and editing team, and the software system was enhanced, completed, and tuned by the new development team. Startup of the client applet was optimized by loading all classes "on demand". Full support of the Windows platform was added (WAVE sound file format, support of the Explorer way to handle multimedia data, etc.), sound transformations became stereo and could be indefinitely chained. The client interface was completely redesigned, became fully resizable and uniform on all platforms (Swing/JFC look and feel), graphically much enhanced by the hierarchical directory view in the sound manager with indication of the download size, graphical break point function editors for time-dependent transformations, menus and tab controls instead of buttons, etc. Many minor improvements were done to the client, the servers, and the various administration tools. Some small but useful features were added, like e.g. the progress messages during transformation processes and the possibility to abort them, the possibility to download multiple sounds in one archive file or to automatically order sounds on CD, and automatic dithering of 8 bit sound. More information is to be found in the release notes [SOL].

8. Some Problems Encountered

We had much trouble when upgrading from the Java 1.0 AWT to the Swing/JFC library. All Swing GUI action is done in the user thread which blocks on synchronous remote method invocations. Since we cannot predict the response time of such remote calls we had to program our own threading policy in order to refresh the user interface during a remote call. We finally decided to launch a thread for each remote connection. But then we had the difficulty of synchronizing these threads, especially in order to prevent a user nervously clicking on the interface and flooding the server with newly opened threads (we realized this problem when during testing, our JDBC drivers simply blocked the whole system without any error message after we hectically clicked some hundred times in the interface). This considerably complicated the programming of the selector interface. We would have wished the Swing/JFC layer to implement the same threading policy as the old AWT.

We also had much trouble with a bug in the Gatekeeper which blocked without any error indication after a couple of days. I shall not mention the dozens of minor bugs in the various Swing/JFC betas and other used software (especially our Java development tool). But the most annoying bugs and deficiencies were found in the browser software: no resizing of the applet in Netscape, no upload of sounds possible with the Explorer on the Mac, to name only the most flagrant ones. Microsoft did not correctly port their current Java Virtual Machine to the MAC, and the Apple MRJ is so sloppily implemented that one has to invent dozens of workarounds in order to be able to use it at all. See [SOL] for details.

9. Future Work

Studio Online is actually a project designed for the future. We used the latest technology available at the time, much to the disenchantment of some of our users which were not able or ready to upgrade to the latest Web Browser versions with a Java Virtual Machines fully compliant to the Java 1.1 API. We needed the new Java version as well as Sunsoft's Swing/JFC classes for the advanced graphics in the applet's user interface. We even would have preferred to migrate to Java 1.2 if it had been available at the time, for it integrates the ca. 2 MB of JFC class code that have to be downloaded on the first use of Studio Online. When using Nescape Communicator which already integrates Visibroker's CORBA classes (albeit

in an older version), the applet could even shrink again to its old size of some hundred KB (which at the time gave it the nickname "JORBA" for "**j**ust **o**ne **r**eally **b**ig **a**pplet"[3]). Java 1.2 would also invite to replace the current CGI driven downloading and playing of audio data by an integrated solution using (an improved form of) the Java Media Framework, with its support of many more file formats, etc.

Despite its success, Studio Online should be considered only the beginning of a much more ambitious project of internetworked sound processing, transparently distributed sound storage and access, and the design of component software for music purposes. It has been shown that Studio Online technology can solve some of the problems of a large and historically grown research institution as IRCAM, but there is still a long way to go.

For example, the current integration of IRCAM sound processing tools works by command line wrapping which is a tedious, limited and suboptimal way to expose them to remote use. There are 3 to 8 separate processes launched per transformation: the various sound conversion tools to feed the source sound into and to retrieve the processed sound from a command pipeline, the splitting of stereo sound into mono channels for the Additive engine which itself is but a script executing command lines. Under these conditions, it was already an achievement to implement such basic remote controls as a gauge to monitor the progress of a transformation and a button to remotely abort the transformation process!

Instead of launching shells executing assembled command line strings, the sound processing engines should be encapsulated as multithreaded CORBA servers. Once there will be stable versions and well-defined control interfaces of these engines, it will be much easier to develop intuitive and fault-tolerant integrated systems using them. It would then be feasible to develop unified graphic interfaces for expert configuration of these sound processing engines which have remarkable possibilities if used in advanced mode.

Studio Online should develop into a testbed for advanced tool integration, sound internetworking, and audio research with the help of distributed objects. There is no lack of ideas: projects have been conceived of treating the integration of distributed databases, advanced content search in audio documents (instead of the current table lookup), integration of more IRCAM software, etc.

10. Conclusion

Studio Online has been one of the few realizations answering the call for projects on the "Information Highway" that have been successfully completed in time. This fact makes it all the more deplorable that there has not been any kind of immediate follow-up project. Aside from the fact that much more functionality could have been added to and on top of Studio Online, it is with the expertise gained during this project that even more interesting inter/intranet applications of distributed processing for musical purposes could have been envisaged.

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[3]Another possible sense of the JORBA acronym could be the combination of **J**ava and C**ORBA** technology.

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