An Annotated and Federated Digital Library of Marine Animal Sounds

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LONG-TERM GOALS

The Macaulay Library is the world's largest archive of animal sounds and has been selected by the Office of Naval Research as a major repository for the deposition, digital archival, review, and retrieval of the many recordings of marine animals made over the last half century. Archived marine recordings pose challenging retrieval problems given the typically long intervals of silence between animal sounds and the multiplicity of species detectable in any given recording. One goal of this project is to design software that will permit remote experts to annotate the content of long recordings archived at the Macaulay Library through their web browsers. Annotations will permit subsequent searches of the archive database to retrieve not only suitable recordings, but also those parts of a recording meeting the search criteria. The project also seeks to define and extract a set of acoustic features from all archived marine recordings that can be used in subsequent search and retrieval tasks. Both capabilities will be unique to this sound collection, and will greatly enhance the accessibility and the utility of the archive to scientists, students, educators, military personnel, and the media.

OBJECTIVES

To achieve the annotation goals, the project must provide a) a browser-based software tool for visualizing and playing back digitized sounds stored in the archive; b) mouse-driven tools for identifying specific segments within the visual image of the sound; c) pull down menus that allow the annotator to assign standardized metadata terms for annotation as well as entry of custom notes to specific segments within recordings; d) suitable metadata structures for storage of the annotations and the relevant segment delimitation points and linkages to other relevant metadata fields; e) search

engines that support the invocation of annotation terms during searches along with other standard criteria; and f) retrieval tools that identify relevant parts within archived recordings, mount the recording, create a visual image, and move to the relevant annotated segments. All of these tools must allow multiple annotators to add information to the same recording, and search engines that permit either all-annotator or specific-annotator searches. To our knowledge, no archive currently provides suitable tools to meet these requirements. They thus must be created from scratch by this project.

To achieve the extracted feature goal, we need to: a) obtain a consensus from the marine acoustics community on which common measures would best facilitate their use of the sound archive; b) create the relevant algorithms and test them; c) implement the algorithms so that they can be applied directly to annotated segments in the archive; and d) provide suitable metadata structures to store the extracted feature data and link them to the other fields pertinent to any recording. At some later date, automatic batch signal detectors and segment delimiters will be developed that will allow extraction on all recordings, whether yet annotated or not. However, that step is not part of the current project.

APPROACH AND WORK PLAN

The annotation and feature extraction software tools are both complex tasks because they require seamless integration of visualization, user input, database design and manipulation, search engine, and web usability components. The tasks have been broken into discrete modules and specifications written for each module, including definition of deliverables and due dates. The Macaulay Library metadata model required a major reconstruction and transfer into an Oracle relational environment. Critical to this effort was the incorporation of existing or development of new metadata standards for habitat type, taxonomy resolution, and classification of associated behaviors. All software for search, retrieval, and manipulation is being written in Java to ensure cross-platform compatibility. The visualization tool, (creating spectrograms and waveforms of any archived sound), posed unique challenges because it had to work in a browser environment, handle both audio and video archived files, guarantee proper digital rights protection, be instantaneous in operation, allow for segment selection by remote users, and meet the high standards for spectrogram resolution demanded by the marine bioacoustics community. Our solution has been to build this tool using Apple Quicktime, a utility available on all user platforms for free and providing all the necessary requirements. The feature extraction tools require input from the marine bioacoustics community at all stages. This is being handled by a) including critical members of that community as partners in the project, b) holding workshops where optimal features can be discussed, and c) recruiting testing and critique input from a variety of marine bioacoustics labs throughout the United States as algorithms are implemented.

Marc Dantzker, Curator of Visual Media and Programming at the Macaulay Library is overseeing the management of the software projects. Head programmer William Sandner delegates JAVA tasks and works on the critical parts of the modules. Jon Josephs writes functional specificiations for each module, and writes software for specific ones. Rafe Rosen and Gui Iacino each work on programming other modules in the project. Erica Olsen is our web interface designer and usability tester. Tim Levatich handles all the metadata modeling, implementation, and database management. Roger Slothower is developing the mapping tools. The Quicktime visualization tool is being developed by Totally Hip Technologies, Inc., a Vancouver, British Columbia company that specializes in Quicktime extensions. The Bioacoustics Research Program at the Cornell Lab of Ornithology, including partners Dr. Chris Clark and Kurt Fristrup, are providing critical input on the optimal design of the visualization tools and the feature extraction module. Partner Dr. David Mellinger has also provided critical input on feature selection, and will implement the initial algorithms in a Matlab environment so that they can be

distributed, examined, and critiqued by participating marine bioacoustics laboratories around the country. Dr. Sue Moore, another partner, will be providing critical assistance in recruiting suitable participant labs and in feature selection.

The annotation project is well underway (see below), and we expect to post the initial version on the website during Spring 2005. Subsequent work the remainder of the year will focus on refinement and correction of any problems in the site, creation and implementation of interactive mapping tools (both for archival and for search/retrieval functions), and creation of the initial steps needed to federate the Macaulay Library archive with the OBIS/Seamap geographic site, also supported by ONR.

The feature extraction project is still in the stage of identifying candidate features for implementation. The goal for the coming year is to implement these in Matlab, distribute them to participating marine acoustics labs, and solicit feedback on design and efficacy of the measures. Once the final set, (currently estimated at 20 features), is ready, a server at the Macaulay Library will be outfitted to perform extractions on all recordings as they are annotated. These extracted features will then become available for searches along with the annotations and other metadata fields.

WORK COMPLETED

The revision and structuring of the metadata model in Oracle to accommodate the relevant fields is now complete. This includes access to habitat, taxonomic resolution, and behavior classification standards. JAVA routines for search and viewing search results have been written and implemented in newly designed web pages (Fig. 1). These pages are currently being tested for usability.
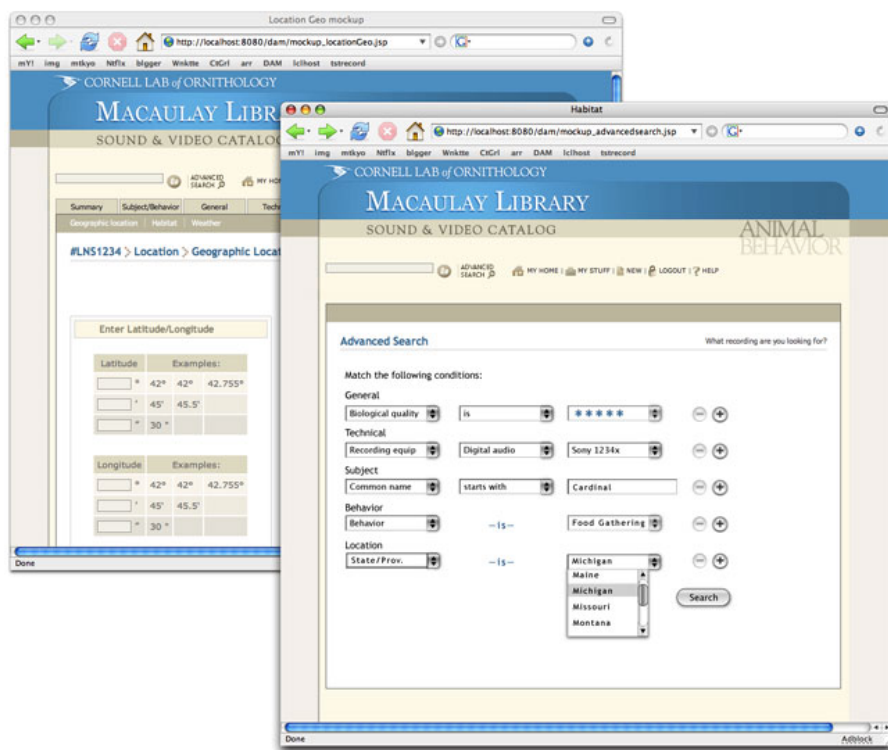

Figure 1. Sample web pages showing search options for accessing marine sound archive

The visualization tool has proved challenging, but is now nearing completion. The spectrogram tool functions extremely efficiently with good resolution, and the Quicktime environment provides the expected digital rights protection while being universally accessible. An example of a browser-generated spectrogram showing a spectrogram of a humpback whale song is provided in Fig. 2.
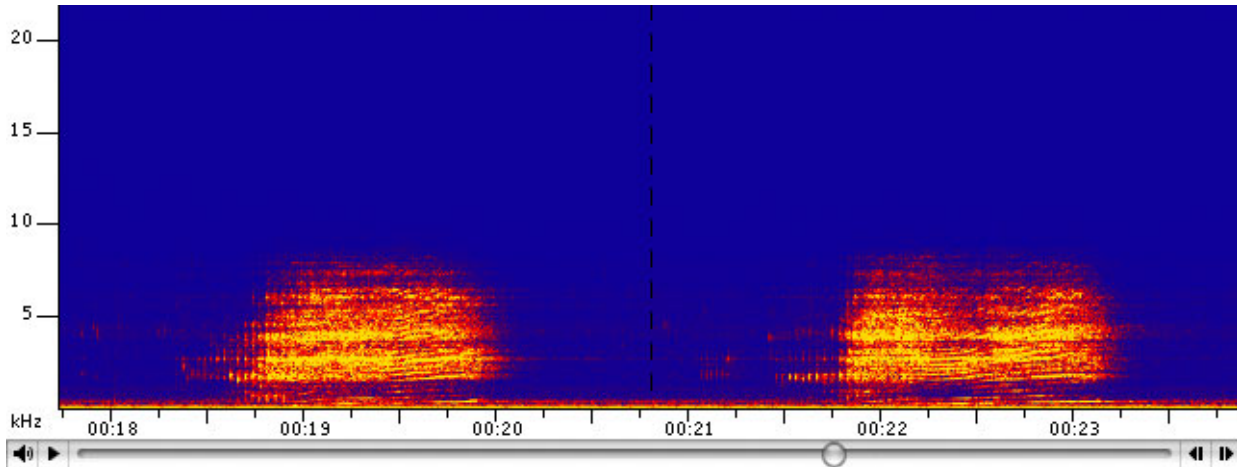

Figure 2. Browser/Quicktime spectrogram of humpback whale song notes. Spectrogram moves during playback so that dotted line indicates current section being replayed.

The waveform display is currently being completed so that users can see either or both visualization of a sound.

Playback causes the visual image (whether spectrogram or waveform or both) to move such that the part being played will pass under a fixed dotted line in the window. Users are able to customize spectrogram time scales, frequency scales, bandwidth, overlap, brightness, contrast, and color scheme. They are also able to mark segments for annotation or download. While meant only for browsing archived sounds, (not analyzing them), the current tool provides sufficient information that users can choose intelligently between alternative sounds for subsequent download. Access to the visualization tools will be free to all users of the site.

The feature extraction project hosted one workshop in August 2004 at which considerable progress was made on how to identify and implement suitable features. Tools have been developed in Matlab for distribution and examination by participating marine acoustics laboratories. An initial list of features for implementation and distribution is currently being completed by Dr. Kurt Fristrup of the Cornell Bioacoustics Research Program.

RESULTS

Major results from this last year include the creation of a proposed new metadata standard for the classification of animal behavior (http://ethodata.comm.nsdl.org/), an online tool produced in collaboration between the Cornell Lab of Ornithology and uBio (http://www.ubio.org/) for resolution of taxonomic synonymies, and development of a browser-compatible platform-independent sound visualization tool that includes appropriate digital rights protections.

IMPACT AND APPLICATIONS

National Security

While the U.S. Navy has its own archives of marine animal sounds that can be used to discriminate between man-made devices and animals, the new Macaulay Library archive is likely to become a broader and more definitive source as it grows and users become more adept at exploiting the new tools to identify and retrieve specific sounds. The military will of course have full access to the entire collection.

Economic Development

Both commercial and public media frequently seek examples of sounds of newsworthy species from the Macaulay Library. The new tools developed here will make such requests much faster and effective as the media themselves will be able to search and audition sample sounds remotely on the web, pay, and download the sounds immediately.

Quality of Life

Most marine animal conservation programs rely on bioacoustic monitoring to assess community health, diversity, and activity. Providing an immediately accessible voucher collection online will greatly facilitate all such efforts.

Science Education and Communication

The marine acoustics research community urgently needs a common repository of sounds of each marine species engaged in different activities. The Macaulay Library has volunteered to build such a site and is well on its way with over 500 hours of digitally archived recordings covering 56 species of marine mammals and 130 species of fish and invertebrates.

TRANSITIONS

Economic Development

The Macaulay Library is a major resource of sound and video recordings for public and commercial media, museums, zoos and aquaria, producers of products reproducing animal sounds, wildlife identification devices, CD and DVD nature productions, sound effects for the movie industry, etc.

Quality of Life

Macaulay Library provides sounds for web-based and kiosk public information sites, training tapes for bioacoustic censusing by wildlife biologists and conservation staff, workshops to train wildlife recordists and bioacoustic censusing staff, etc.

Science Education and Communication

Macaulay Library is one of the world's primary resources for archived sounds of animals and is thus widely used by scientists, teachers, and students. It is also an active member of the National Science Digital Library program.

RELATED PROJECTS

Macaulay Library also has a concurrent grant from the NSF-funded National Science Digital Library program to maintain an NSDL portal and web pages that will maximize access and utilization of the

animal sound and video collections for education at all levels. It has another (smaller) NSF grant to fund the development of an international metadata standard for the field of animal behavior. Finally, ONR is supporting generously the archival of the last half-century's accumulated field recordings of marine animals at the Macaulay Library. This has included funds for both equipment acquisition and staff salaries for archivists.