CCRMA Studio Report

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Abstract

Stanford University's Center for Computer Research in Music and Acoustics (CCRMA) is still a multi-disciplinary facility where composers and researchers work together using computer-based technology as both artistic medium and research tool. This studio report covers CCRMA's people, facilities, and activities (research, musical, and educational) with emphasis on recent changes and on CCRMA's contributions to the computer music community at large.

1 People

The CCRMA community consists of administrative and technical staff, faculty, research associates, graduate research assistants, graduate and undergraduate students, visiting scholars and composers, and industrial associates.

Staff & Faculty: Chris Chafe: Director, Professor of Music; Jonathan Berger: Associate Professor of Music; Max Mathews: Professor (Research) of Music; Julius Smith: Associate Professor of Music and Electrical Engineering; Marina Bosi: Consulting Professor of Music; Walter Hewlett: Consulting Professor of Music; Eleanor Selfridge-Field: Consulting Professor of Music and Symbolic Systems; John Chowning: Professor of Music (Emeritus); Leland Smith: Professor of Music (Emeritus); Christopher Burns: Technical Director, Lecturer; Jay Kadis: Audio Engineer, Lecturer; Fernando Lopez-Lezcano: Systems Administrator, Lecturer; Malcolm Slaney: Lecturer; William Verplank: Researcher, Lecturer; William Schottstaedt: Research Associate; Richard Humphrey: Assistant System Administrator; Vibeke Cleaver: Administrative Assistant; Tricia Schroeter: Administrative Associate.

Here are the categories of students at CCRMA and their approximate current populations. There is a Music Science and Technology ("MST") specialization for undergraduate music majors (6) and minors (1); other undergrads inside and outside the music department take CCRMA courses as electives (dozens). CCRMA offers a coursework-intensive one-year Master of Arts degree in MST (7). CCRMA offers a PhD program in Computer-Based Music Theory and Acoustics through the music department (17); thanks to Julius Smith's dual appointment with Electrical Engineering we also host and advise some EE PhD students (7). Some Doctor of Musical Arts (composition) students (of 9) also study and/or work at CCRMA. Stanford also has interdisciplinary undergraduate and masters programs in Symbolic Systems; some of these students concentrate in Computer Music (3).

Current and recent visiting scholars include Moto Abe from Sony, Antoine Chaigne from the Ecole Polytechnique in France, Peter Desain from the Nijmegen Institute for Cognition and Information in the Netherlands, composer Christopher Keyes from the Hong Kong Baptist University, composer Peer Landa, pianist Chryssie Nanou, composer Jesper Nordin, and composer Peter Traub.

2 Courses

CCRMA teaches about 20 Stanford courses. MST students (both undergrad and MA) take a 3-course series on theory and practice of sound recording technology; a 3-course series on theory and practice of computer music (using environments including Pd, Common Lisp Music, the Snd sound editor, Audacity, and C++ programming with the Synthesis Toolkit); Acoustics; Psychophysics and Cognitive Psychology for Musicians; and Human/Computer Interaction ("HCI", covering sensors, elementary electronics, Atmel microprocessor programming in C, Open Sound Control, Pd, and theory of interaction design). MA and PhD students also take the Introduction to Digital Audio Signal Processing, emphasizing the mathematics of the DFT and of digital filters with lots of matlab programming. Many students continue the DSP series with Audio Applications of the FFT and the course on computational acoustic modeling for digital audio effects and sound synthesis.

Our newest course offering is Signal Processing Techniques for Digital Audio Effects, taught by Jonathan Abel and David Berners from Universal Audio. Other CCRMA courses include Musical Information: An Introduction, Research Seminar on Computational Models of Sound Perception, Perceptual Audio Coding (Bosi and Goldberg 2002), Auditory Remapping of Bioinformatics, Orchestration and Timbral Analysis, and the CCRMA DSP seminar. Musique Concréte in the Digital Era is a new course based on listening and composing that attracts many non-music majors.

Stanford has two programs for putting undergraduates in close contact with faculty; CCRMA's participation in both successfully hooks teenagers on computer music. "Stanford Introductory Seminars provide opportunities for first- and second-year students to work closely with faculty in an intimate and focused setting"; CCRMA's version,

"Technology and the Arts," draws upon a select group of freshman who explore the confluence of technology and the arts from historical, sociological, aesthetic, and creative perspectives. Project themes such as "creative extensions of the game of broken telephone" provide a framework for investigating issues of interaction (or lack thereof), notation (or lack thereof), distortion (or...), etc. Recent term projects included computer based dance notation, subliminal messaging, analogies between visual and audio filter techniques, regional influences on hip-hop, musical automata, and technologies of bowed string construction. Stanford's Sophomore College program "offers sophomores the opportunity to study intensively in small groups with Stanford faculty for several weeks before the beginning of fall quarter." In CCRMA's version, "Sound, Digital Sound, and Massive Sound Media," a dozen sophomores meet for 2 weeks full-time in an all-out course concerning sound, digital sound, music-making and synthesis. Daily lab sessions feature forays into instrument building, underwater acoustics, and hearing. Students have produced and performed public concerts, visited industry and studio locations, and heard guest lectures on everything from sound on Mars to automatic composition.

We also offer seminars, special interest group meetings, spring and summer workshops, and colloquia. This year we are pleased to teach 8 solid weeks of summer workshops in Banff, including Physical Interaction Design, Robotic Controllers & Force Feedback, Sinusoidal and Physical Modeling, Advanced DSP, Audio over Networks, and Perceptual Audio Coding.

3 Facilities

CCRMA is located on the Stanford University campus in "The Knoll," a building that was originally the university president's mansion, then the home of the music department, then refurbished in 1986 to meet CCRMA's unique needs, then seriously damaged by the 1989 Loma Prieta earthquake and partially condemned. By the time of this conference we hope to have begun an extensive renovation and seismic upgrade that will include a new 100-seat performance venue, a "Listening Room" where listeners will sit on a grid floor surrounded by a full-spherical array of loudspeakers, and improved spaces for teaching and research, while retaining the building's historical character.

Today, CCRMA's ground floor contains a fully digital recording studio with adjoining control room, a couple of ProTools-equipped studios for mixing and editing and a Macintosh lab; these facilities are used by the recording and Musique Concréte courses and by composers. The main floor contains a large multichannel/multimedia experimental space (where most classes and concerts are held), an adjoining control room/all digital studio with an 8-channel 3D surround speaker system (speakers at the vertices of a cube), an extensive hardware lab for HCI research, our popular sensor-equipped foosball table, and several work areas with workstations. The third floor is currently considered unsafe because of earthquake damage, except for the library, which is also used for seminars. (The library is also the home of a still-functioning NeXT workstation!) CCRMA currently also occupies some temporary trailers behind the Knoll, consisting mainly of offices and workstation clusters.

CCRMA's over 30 workstations are a mix of 270 Mhz to 3Ghz Intel-based machines with 24bit/96KHz stereo I/O through Midiman Delta 66 cards and OmniIO external mixer boxes, permanently attached headphones, MIDI interfaces, and serial connections for talking to the AVRmini HCI development platform (Wilson, Gurevich et al. 2003). (Workstations in the studios have 8-channel audio I/O via ADAT lightpipe.) These are all Planet CCRMA machines running Red Hat Linux 9 (currently the 2.4.25 kernel) with Andrew Morton's low-latency patches, Robert Love's preemptible kernel patches, the "capabilities" patch that allows non-root users to run processes at real-time priority, the ALSA sound driver, the Jack sound server, and the entire Planet CCRMA collection of audio, music, and multimedia software. Any CCRMA local user (of which there are now about 145) can sit down and log into any of these machines and access the same file system hierarchy, including home directory, web sources, and 500G "snd" disk. This consistency of hardware, software, and configuration among these machines (thanks to the tireless systems administration staff) results in a community culture in which faculty, staff, undergrads, and grads all sit side by side in common spaces to work and play.

4 Research

It would be impossible to cover all of CCRMA's research activities within the scope of this report. Instead we will outline some of the major themes and give the titles and perpetrators of the active projects, loosely organized by theme. For more details, see the CCRMA Overview (ccrma.stanford.edu/overview/research.html), and our "Research Groups" page (ccrma.stanford.edu/groups).

Sinusoidal Modeling

- Sinusoidal modeling and effects; Guillermo Garcia
- Time-varying sinusoidal modeling; Aaron Master

Physical Modeling

- Modeling instruments from the flute family; Patricio de la Cuadra (Music PhD diss.)
- The sound of friction: realtime models, playability and musical applications; Stefania Serafin (Music PhD diss.)
- Applications of bioacoustics to the creation of new musical instruments; Tamara Smyth (Music PhD diss.)
- Technique for creating, evaluating and refining digital synthesis models of cetacean acoustic signals (whale song); Michael Gurevich
- Digital filter design for dispersive piano-string modeling; Julius Smith and Julien Bensa

Artificial Reverberation

- Visualization of reverberation and objective evaluation of subjective quality of reverberant tails; Patty Huang
- Artificial reverberation using the digital waveguide mesh; Patty Huang (Music PhD diss.)
- Application of Schroeder quadratic residue diffusers to the digital waveguide mesh; Kyogu Lee

Digital Audio Effects

- Dynamic range compression based on models of time-varying loudness; Ryan Cassidy
- Nonuniform, oversampled filterbanks; Ryan Cassidy

Statistical Audio Signal Processing/Modeling

- Bayesian multi-source modeling for stereo sound source separation; Aaron Master (EE PhD diss.)
- Audio source separation; Pamornpol Jinachitra
- Extracting audio sources from musical recordings using measures of independence and sparsity; Randal Leistikow (Music PhD diss.)
- Bayesian identification of closely-spaced chords from single-frame STFT peaks: Randal Leistikow and Harvey Thornburg
- Transient detection and modeling; Harvey Thornburg
- From spectral pitch estimation to automatic polyphonic transcription; Harvey Thornburg (PhD diss.) and Randal Leistikow
- An iterative filterbank approach for extracting sinusoidal parameters from quasi-harmonic sounds; Harvey Thornburg and Randal Leistikow
- Automatic transcription of polyphonic piano music; Randal J. Leistikow
- A new probabilistic spectral pitch estimator: exact and MCMC-approximate strategies; Harvey Thornburg and Randal Leistikow

Audio Coding

- Audio watermarking based on parametric representations; Yi-Wen Liu (EE PhD diss.)
- Audio coding, digital media development and deployment, specifically, perceptual audio coding, psychoacoustic modeling (e.g., masking summation), multi-rate algorithms (e.g. integer MDCT), data hiding; Marina Bosi

Music Analysis

- A method of automatic recognition of structural boundaries in recorded musical signals; Unjung Nam (PhD diss.)
- Automatic transcription of solo tabla music; Parag Chordia (Music PhD diss.)
- Computational models for musical style identification; Yi-Wen Liu and Craig Sapp
- Classification of operatic soprano type (coloratura, lyric, or dramatic) with formant-frequency modeling; Sook Young Won
- Analysis, Classification, and Synthesis of Indian music and ragas; Arvindh Krishnaswamy
- Automatic detection and classification of ragas in South Indian classical music; Arvindh Krishnaswamy
- Indian Music Theory, Perception, cognition & Psychoacoustics; Arvindh Krishnaswamy
- Harmonic visualizations of tonal music; Craig Stuart Sapp
- Themefinder: a musical theme search engine; Craig Stuart Sapp
- Setting a menu to music: intonation and melody in 19th century art songs; Leigh VanHandel

Musical Networking

- Effect of time delay on ensemble accuracy; Chris Chafe, Michael Gurevich, Grace Leslie, Sean Tyan
- Distributed internet reverberation for audio collaboration; Chris Chafe

Composition Research

- Signal processing techniques for algorithmic composition; Christopher Burns (Music PhD diss.)
- Music score phonetization and speech-derived composition; Rodrigo Segnini

Software Systems

- Complete port of CLM into the Snd Scheme and Ruby environments; Bill Schottstaedt and Michael Scholz
- Ongoing Snd development: virtual editor, UI improvements, track mechanism; Bill Schottstaedt

Miscellaneous

- Haptic interfaces for audio navigation; Lonny Lung-Yin Chu (Music PhD diss.)
- Modeling buffer over-run/under-run occurrences in low-latency audio signal processing on personal computer platforms; Ryan Cassidy
- Audio and Gesture Latency Measurements on Linux and OSX; Matthew Wright and Ryan Cassidy

CCRMA's research in sonification and auditory display includes a DARPA-funded project on representing complex highly dimensional data using vocal tract and other physical models, and development of a flexible toolkit for remapping sensory data. Current applications range from sonification of hyperspectral medical imaging data to auditory display of network traffic (ccrma.stanford.edu/groups/soni).

As a result of research in denoising historical recordings, a substantial collection of Edison wax cylinder recordings and players was bequeathed to CCRMA for research and pedagogical uses. This forms the basis of the William H. Nieman Collection of Historical Recordings (ccrma.stanford.edu/groups/edison).

5 Music

Recent compositional works realized at CCRMA (see ccrma.stanford.edu/overview/composition.html) include the following:

- Jonathan Berger, *Diameters* (2003) for mezzo-soprano and computer.
- Christopher Burns, *The Language of Pilots* (2004), for solo percussion, *Labyrinth* (2003), a "telepresence improvisation environment,"*Hero and Leander* (2003) for multichannel tape.
- Chris Chafe, soundtrack to animated film *Organum,* physical models driven directly from animation data.
- Damián Keller, *Paititi: a multimodal journey to El Dorado* (2003) an installation.

- Jonathan Norton, *Return to C* (2003) for solo harp
- Juan Reyes, *Feather Rollerball* (2002-03) for piano, radio baton and scanned synthesis, *Freddy the Friedlander* (2003) for multichannel tape.
- Gary Scavone, *Pipe Dream* (2003) for custom MIDI wind controller and realtime computer synthesis.
- Peter Traub, *10five1* (2003) for tape, *portfoliosis* (2003) for tape

Research in sonification also has a creative side with sonified data ranging from solar storm measurements to hyperspectral diagnostic data of human cells used in compositional contexts. Stanford's recently opened Clark Center, hosting the Bio-X program, commissioned both an installation and a work for computer and string quartet using sonified bioinformatic data from Jonathan Berger.

CCRMA music (by Berger, Chafe, Burtner, Nichols, and Suzuki) was featured in the 2004 Pan music festival in Korea.

Many CCRMA students participate in Prof. Mark Applebaum's Stanford Improvisation Collective ("[sic]"); this year he encouraged a group of us to create and play interactive electronic instruments for this ensemble.

We present several concerts of computer music each year, including the "Strictly Ballroom" concerts (http://ccrma.stanford.edu/events/ballroom) produced approximately monthly by Chris Burns, the newly invigorated "Alea II" concert series featuring graduate composers, an annual outdoor computer music festival in July, and exchange concerts with institutions such as Harvard & Brandeis Universities, with U. Washington / CARTAH, Brooklyn College, and UC Berkeley's CNMAT.

Notable recent concerts by visiting artists included composer/pianist Christopher Keyes, composer Jeffrey Stolet, composer/doublebassist Stefano Scodanibbio, pianist Chryssie Nanou, and a three-day, nine-concert festival in April 2003.

6 Sharing Our Work

CCRMA strongly encourages the sharing of our work with the computer music community at large. As you can see above, we are strongly committed to open source projects including the Linux OS and almost all of the software taught at CCRMA. (We are even moving gradually from the commercial Matlab to the mostly equivalent open source Octave, including contributing free reimplementations of Matlab features missing in Octave.) Almost all of the generally useful computer music software developed at CCRMA is open-source, including the Synthesis Toolkit, Snd (known to some as "the Emacs of sound editors"), Common Lisp Music and related environments.

The Linux packages installed at CCRMA are collected into a distribution called Planet CCRMA (http://ccrma.stanford.edu/planetccrma/software) that is also available to the public. The main advantages of Planet CCRMA are relatively easy installation (orders of magnitude easier than any alternative), well-documented installation instructions, an active mailing list (currently with about 450 members), and a huge number of packages that we continuously keep up to date and recheck for mutual compatibility. A popular music magazine recently ran an article on Planet CCRMA (Metts 2004).

Julius Smith has published three books (Smith 2003; Smith 2003; Smith 2003) to the Web in HTML format in addition to traditional printed book format. These are the textbooks for the music/audio DSP course series and contain a large amount of information (about 1800 pages total) with both a mathematical foundation and emphasis on music. They are extensively interlinked, with the goal that a person should be able to start reading "anywhere" (e.g., coming in from a Google search), and be able to click on any technical term to obtain its "home page," or at least a clear definition with some development. Julius spent his 1999 sabbatical leave developing this interlinking system into the Open Dictionary, a hierarchical, free, online meta-encyclopedia. It takes the form of a "link repository" where anyone can contribute URLs of pages that define terms. Presently, the great majority of "defined terms" are related to musical sound synthesis research and supporting areas, but the scope is expected to expand over time. A ranking system handles multiple competing links for the same term.

CCRMA continues to maintain the Musical Acoustics Research Library (MARL), a collection of independent archives and libraries each originally assembled by a distinguished group or individual in the field of musical acoustics research. Contents include published and unpublished papers, lab notebooks, course notes, correspondence, etc.; anyone can browse the online index and even request electronic scanned versions of (non-copyrighted) documents. http://ccrma.stanford.edu/marl

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