Development of Algorithms for Next-Generation Digital Music Instruments

Concept Paper for Consideration by UTTI

submitted by
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The present decade has seen rapid growth in the application of digital technology to music and many musicians find themselves in day-to-day contact with computers. Digital synthesizers have become common instruments, digital audio workstations are rapidly replacing tape-based recording facilities, compact discs are the current means of dissemination, and even composition and music printing are assisted with a wide range of software.

The limitations that persist in digital synthesizers also plague computer applications in speech and animation. Nothing quite replaces the real thing, in terms of the voice or image quality. And very little has been achieved in synthesizing continuous behavior, for example in the prosody of natural speech or fully automated, life-like, motion with an animated character. A new class of music synthesis algorithms has been tested for simulating certain instruments and shows promising improvements in these regards. The simulations are based on descriptions of an instrument's mechanics and are broadly classed as "physical models." Interesting results have been demonstrated for wind, bowed string, singing voice and percussion instruments.

Total keyboard computer music instrument sales have been reported to have topped three billion dollars since 1981. Stanford University technology was employed in the most popular instruments to date, those belonging to Yamaha's DX-7 series. These instruments use Frequency Modulation (FM) synthesis to create spectral complexes close to natural musical tones. The application of FM to music synthesis was invented at Stanford in 1971, patented, and subsequently licensed to Yamaha. It was for several years the single greatest source of revenue in the Stanford Technology Licensing Program (including biotechnology patents).

Current algorithms for sound production fall into 3 categories, spectral synthesis (of which is FM most common), sampled (playback of short, isolated, recorded tones), and hybrid combinations of spectral and sampled. Each has its particular advantages with regard to sonic details and ease of mastery, and as a result most electronic studios own a combination of instruments (the MIDI standard exists to interconnect any group of instruments).

Physical models constitute a fourth category of algorithm, yet to be employed in any commercial instrument. We propose to UTTI to enter into a period of research of one year resulting in a comprehensive set of physical models implemented on our development system. Previous examples have been demonstrated using various algorithmic approaches spread over various computer systems. These will be consolidated in a systematic way so that a uniform code library could be studied. Ideally, this would provide the basis for a digital instrument design cycle to be pursued by interested parties.

The simulations tested so far have reproduced the detailed dynamical behavior missing from current commercial instruments. Starting transients, connected-note transitions and expressive nuance that goes into playing a musical phrase are extremely good. Control of the sound is intuitive, since the model responds like the instrument to the player's manipulations. Exciting possibilities, as yet unexplored, exist for creating fanciful new instruments whose behavior is rooted in the mechanical constraints of the real world. Our success with the singing voice project also points to the possibility of a path to better computer-generated speech, based on articulatory representations.

The physics of different instrument families can be fairly easily described and representative mathematical models created. Bowed strings and wind instruments are set into vibration when energy is applied through bow motion or breath pressure. Excitation of the vibrating system is governed by a non-linear driving function -- either the frictional characteristic of the bow hairs, or a relaxation mechanism like a reed, a switching air jet or the lips. Stability and pitch of the oscillation depends on wave motion in the resonant element of the system (the string or bore) that is fed back into the excitation function. Several computational models have been devised for the non-linear and resonant components. The power of the method lies in capturing their interaction in the form of a coupled mechanism.

Two researchers presently at CCRMA would undertake the study. At this point, there is no other outside funding for this work at CCRMA. Dr. Chris Chafe is Associate Professor of Music (Research) with five years experience exploring physical models of musical instruments. Perry Cook is a graduate student in the Electrical Engineering Department who expects to complete his Ph.D. in 1990 on a related thesis topic. One year of support is figured in the budget below, the start date commencing as soon as funding is secured. The term of the project might run through calendar 1990, so we would expect to continue Perry in a post-graduate research position through the funding period. Equipment for carrying out the work has been recently purchased by CCRMA , consisting of NeXT workstations and related hardware.

Preliminary Budget

Principal Investigator:		
Chafe	%25 time (12 months)	16,349
Graduate student research assistant:		
Cook	%50 time (6 months) plus %100 (6 months)	22,394
misc. consummable supplies		4,000
total before Indirect Costs		42,742
Indirect Costs (%74)		31,629
total project budget		74,371