

Low-dimensional audio-rate control of FFT-based processing

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Abstract

An new real-time DSP programming environment called Max Signal Processing (MSP), was released this past year for the Apple Macintosh PowerPC platform. This software offers a suite of signal processing objects as an extension to the widely used MAX software environment, and provides new opportunities for musicians and engineers wishing to explore professional-quality real-time DSP. Most important, MSP provides a number of frequency-domain processing primitives that allow for the development of sophisticated frequency-domain signal processing applications. Of particular note is the ability to use of simple waveform-based techniques for low-dimensional audio-rate control of FFT-based processing. Using this approach, the authors are able to dynamically control spectral transformations of considerable complexity, using few parameters. These parameters are familiar and easy to control, and lend well to direct mappings of real-time audio input from musicians to the control of FFT-based DSP.

The Max/MSP environment has two run-time schedulers: the Max "control" scheduler, which is timed on the basis of milliseconds, and the MSP "signal" scheduler, which is timed at the audio sampling rate. In FFT-based processing applications, where changes to the resulting spectrum are infrequent, MSP's control objects may be used to provide control parameters for the processing. This is both precise and economical. However, updating lookup tables at the control rate has band-width limitations. The rapidity with which a lookup table can be altered is limited, giving the filtering certain static characteristics. Using 512 sliders to control individual FFT bins, drawing a filter shape for a lookup table with the mouse, or changing the lookup table data algorithmically provides only limited time-varying control of the filter shape. In addition, the amount of control data represented in a lookup table is large and cumbersome. Significant and continuous modification of a spectrum, as in

the case of a sweeping band-pass filter, is not possible using MSP's control objects, since they can not keep up with the task of providing 1024 parameter changes at the FFT frame rate of 43 times a second (at the audio sampling rate of 44,100 samples per second).

Keeping in mind that the FFT data being filtered is signal data, a more dynamic approach to filtering is to update lookup tables at the signal rate (the audio sampling rate). Using simple oscillators for table lookup, well-known waveform generation and synthesis techniques can be used to provide dynamic control of filtering. FM, AM, waveshaping, phase modulation, pulse-width modulation, mixing, clipping, etc., all have the potential to provide complex, evolving waveforms which can be used as spectral envelopes to provide a high level of flexibility, plasticity, and detail to filtering. The use of operations such as stretching, shifting, duplication (wrapping), inversion, retrograde and nonlinear distortion (waveshaping) also provide comprehensive means for modifying these spectral envelopes (waveforms). Additionally, lookup tables can be read in non-linear fashion; control is not restricted to the linear frequency scale, thus making possible the implementation of a constant-Q bandpass filter.

Audio-rate control of FFT-based processing applies equally well to all FFT-based applications where a high degree of processing control is required at the frame rate. The authors have implemented the above mentioned techniques in the following applications: spatialization (bin-by-bin), denoising, dynamics processing, and cross-synthesis. We believe that these techniques hold great promise for control-intensive FFT-based applications.

Technical Requirements:

- one Macintosh G3 computer (prefer with screen projection) w/ audio input (mic) and stereo output
- one overhead transparency projector
- one CD player
- one DAT player