distributions of the different random variables on a learning set. Finally, a hidden Markov model tracks f_0 trajectories between adjacent frames. The first experiments of polyphonic frequency tracking and voice separation are very promising. The model can be transposed directly to the maximum-likelihood estimation of several harmonic sounds since it already considers more than one f_0 value. [a)]Presently on sabbatical at Ctr. for New Music and Audio Technol. (CNMAT), Univ. of California at Berkeley, 1750 Arch St., Berkeley, CA 94709.

3:05–3:15

Break

3:15

4pMU4. Frequency tracking of solo and duet passages using a harmonic two-way mismatch procedure.
Robert C. Maher (Dept. of Elec. Eng., Univ. of Nebraska, 209N WSEC, Lincoln, NE 68588-0511) and James W. Beauchamp (Univ. of Illinois at Urbana–Champaign, Urbana, IL 61801)

Estimation of the fundamental frequency ($F0$) of quasiharmonic signals is an important task in musical acoustics. Many existing techniques have unsatisfactory performance due to octave errors, noise perturbations, and other artifacts encountered in practice. Our work in this area, begun in 1986, uses the quasiharmonic assumption to guide a search for an estimated $F0$, based on the McAulay–Quatieri short-time spectrum measurement procedure. Estimation of $F0$ involves a two-way mismatch calculation where the discrepancy between the measured partial frequencies and a harmonic search grid is used to refine the $F0$ estimate. Inaccuracies present in the measured partial frequencies are averaged over all the available partials, thereby improving the $F0$ prediction. A heuristic weighting scheme is used to help reduce the susceptibility of the procedure to noise or partials missing in the spectral data. The frequency search strategy has also been extended to fundamental frequency estimation of duet (two voice) polyphony. Results for $F0$ tracking of solo and duet recorded musical instrument passages will be demonstrated.

3:45

4pMU5. Live-performance frequency and feature extraction for synthesis control.
Keith McMillen (Zeta Music Systems, Inc.) and David Wessel (Ctr. for New Music and Audio Technol. (CNMAT), Univ. of California at Berkeley, 1750 Arch St., Berkeley, CA 94709)

Musical frequency and feature extraction techniques for guitars and other string instruments are described. These methods obtain rapid and accurate estimates of frequency, intensity, and related spectral features to be used for synthesis control in live musical performance. Live-performance control imposes severe constraints in that the string interface and the synthesis system to which it is attached must respond with the control intimacy characteristic of an acoustic instrument. This requires extremely rapid frequency determination, which is accomplished by using fingerboard information in combination with the acoustic signal from the string. For the guitar, a fret scanning system has been developed to provide an estimate prior to the sounding of the note. Specialized sensor technologies are used to isolate the individual strings. Waveform features are timed to obtain period estimates used to continuously update the initial information from the fret scan. This combination of fret-scan information and period estimation from the signal provides for very accurate tracking and synthesizer notes can be started within 2 ms of the string excitation. It will be demonstrated that the MIDI protocol imposes severe constraints on control intimacy. A more suitable communications protocol for synthesis control and a new generation of instruments that provide an intimate link between instrument interface and synthesis are presented.

4:15

4pMU6. An automatic musical frequency detection and MIDI control system for brass instruments.
Perry R. Cook (Stanford Ctr. for Comput. Res. in Music and Acoust., CCRMA, The Knoll, Stanford Univ., Stanford, CA 94305), Dexter Morrill (Colgate Univ., Hamilton, NY 13346), and Julius O. Smith (Stanford Univ., Stanford, CA 94305)

Fundamental frequency detection algorithms optimized for use with instruments in the brass instrument family are presented. A new frequency tracking scheme based on adaptive periodic prediction is presented, and it is shown that this algorithm is equivalent to a high-precision adaptive comb filter. Frequency detection schemes that do not take into account the unique spectral and acoustical properties of a particular instrument family usually generate errors of three types: (1) octave and harmonic detection errors, (2) half-step errors that jitter rapidly about the true estimate, and (3) latency of detection. A frequency detection and live MIDI control system has been constructed for the trumpet, which significantly reduces detection errors and latency. By limiting the search range to the natural playing range of the trumpet, sampling rate and computation can be optimized, reducing latency in the estimates. By measuring and