Computational and Subjective Procedures for the Assessment of Sounds with Weak Tonal Components

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Abstract There is, as yet, no satisfactory method for the measurement of time varying weak tonal components embedded in complex technical and natural sounds. A new method is proposed based on a model of pitch sensation which accounts for the time and frequency resolution as well as for masking properties of the human ear. The new model fares well, both in assessing the tonalness of pure tones presented at various T/N ratios and of tonal narrow-band noise components.

INTRODUCTION

A discrete tone is defined as "prominent" if the level of the tone exceeds the level of the noise contained in its critical band by 6 dB. Weak and time-varying tonal components in tire sounds often fall short of this level, but are nevertheless rated as prominent by test drivers. For the measurement of weak time-varying tonal components embedded in complex technical and natural sounds there is no satisfying method available yet.

The "tone-to-noise ratio" (T/N) uses the ratio of tone power to noise power within a critical band. The assessment of multiple tonal components with the T/N method is quite limited as shown by Bienvenue and Nobile (1). Their "prominence ratio" (PR) fares better with multiple tonal components. The PR computes the ratio of the total power of the critical bands containing the tone to the average power in the immediately adjacent critical bands.

The PR however, assigns the same values for a narrow-band noise as to a pure tone having the same "T/N"-ratio, which disagrees with the perceptual impression. The Standard ECMA-74 makes a useful correction for the T/N-ratio for the case of multiple tones. However its practical application seems to be limited to non time-varying sounds. A psychoacoustical approach should take into account the time and frequency resolution as well as masking properties of the human ear. Tonalness is closely related to the sensation of spectral pitches which depend upon the sensation level, bandwidth, duration and frequency of the tonal components present. In (2) we proposed a pitch model in order to take these properties into account. From a Fourier-Time-Transformation (FTT, 3, 4, 5) a Part-tone-time-pattern (4, 5) is derived containing possible candidates for tonal components in the frequency domain. In the time domain components lasting long enough to be detected by the human listener are connected to form the Part-tone-line-time-pattern (5) out of which the spectral pitch is derived.

EXPERIMENT

An original tire sound recorded in the laboratory with a dummy head sitting at the drivers seat served as background. A third octave spectrum of this sound is indicated by the vertical bars shown in Figure 1. Pure tones of 500 Hz with T/N-ratios of 3, 6, 9, 12, 15, 21 dB and narrow-band noises (NBN) centered around 500 Hz having bandwidths of 10, 50, 100 and 200 Hz were added to this background. The total power of the narrow-band noises was kept constant at the level of the pure tone having a T/N-ratio of 12 dB. All sounds were rated by 25 observers on a category scale ranging from "not tonal" to "very tonal".

RESULTS

Although the T/N-ratios are rather high, the perceived tonalness of the sound is rather low due to partial masking of the tonal components by low frequencies. The NBN apparently can not correctly be assessed by the prominence
ratio method. The T/N ratio does even worse, overestimating tonal components, since masking is not taken into account. Figure 2 illustrates the performance of the pitch model. The gray bars in Figure 2 show the mean values of the categorical judgements of the sounds. The subjective results are very well predicted by the pitch model (r=0.96). Thus the new approach seems to provide a useful method in order to measure the tonalness of non time-varying as well as time-varying sounds.

REFERENCES


