On the pitch strength of harmonic complex tones

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Introduction

Pitch strength has been the topic of various investigations, experiments and publications. So far a lot of data has been collected to describe the perception of pitch strength for many different stimuli like sinusoids, harmonic complex tones and combfilter noises (e.g. [1]). Each of these give hints on how pitch strength might be processed by the human hearing system, but so far no consistent model is known (to the authors) that is able to describe all pitch strength phenomena.

This paper shows some results for the pitch strength of virtual pitches and tries to use a modified algorithm for the calculation of pitch salience as introduced by Terhardt in [2] to calculate pitch strength. Resulting data is shown in comparison to experimental data.

Motivation

In figure 1 the experimental results for an investigation on pitch strength of the virtual pitch of harmonic complex tones with a varying number of removed lowest harmonics is shown. The results indicate that pitch strength decreases as the number of missing lowest harmonics rises. Pitch strength decreases about 20 percent per removed harmonic for the signals used in the experiment.

Based on this data the question arose in which way pitch strength of these sounds decreases when the level of the fundamental component (f_0) is reduced. The expectation is that the pitch strength will decrease until a certain damping of f_0 is reached and for lower levels of f_0 the pitch strength remains constant as the virtual pitch becomes dominant over the spectral pitch component.

Experimental setup and procedure

The procedure of magnitude estimation with an anchor-sound was chosen for the experiments. Thereby pairs of stimuli with a duration of 0.5 seconds were presented with pauses of 0.4 seconds inbetween at a constant overall level of 60 dB.

The stimuli used were harmonic complex tones at fundamental frequencies 125, 250 and 500 Hz. Additionally the dependency on the spectral damping per octave was investigated using a spectral damping of 0, 3 and 6 dB per Octave.

All pairs of sounds were presented in random order to avoid effects of adaptation. By presenting pairs of same sounds, the subjects' concentration and reliability were also tested.

Results and discussion

In figure 2 the experimental results are shown as medians and interquartile ranges over all 10 subjects. The expected results occured in a way that for a damping of

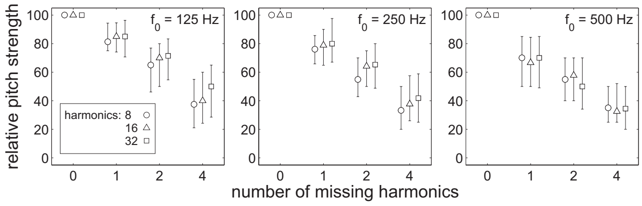

Figure 1: *Experimental results for the strength of the virtual pitch of harmonic complex tones with a certain number of missing lowest components.*

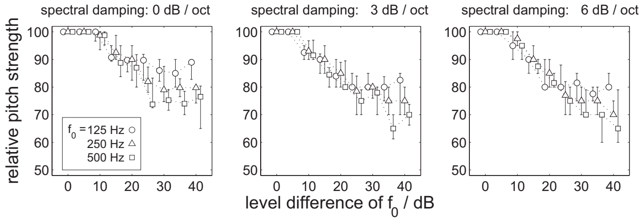

Figure 2: *Experimental results for the pitch strength in dependency of the damping of f_0 for harmonic complex tones.*

f_0 of more than about 20 to 30 dB, the pitch strength reaches a constant value of about 70 to 80 percent which reflects the values found in the experimental data shown in figure 1.

Additionally a dependency of this decrease on the spectral damping can be observed. This dependency shows in a way that for a larger spectral damping the pitch strength decreases less than for lower spectral dampings. To explain these facts, one has to take into account the properties of the human hearing system when seen as a signal analyzer as described in [3] in addition to the theory of virtual pitch described in [4]. Using these models, it becomes obvious that pitch strength decreases less for lower fundamentals as the perception of such sounds is dominated more by the higher harmonics due to the spectral dominance of pitch perception. As these higher components are unaffected by the damping of the lowest component, pitch strength is influenced less.

The effect of saturation of course is due to the fact that virtual pitch becomes dominant over spectral pitch as already stated above. As at higher frequencies the auditory system is able to resolve the fundamental component in a better way than for lower f_0s, the change of this component is perceived more significant and thus leads to a higher influence on the pitch strength.

The dependency on the spectral damping is only very weak but shows that for a higher spectral damping, the lowest component can be perceived better and thus, as for the spectral position, the changes of f_0 can be followed better by the hearing system.

Quelle: DAGA 05, München, DEGA, Berlin

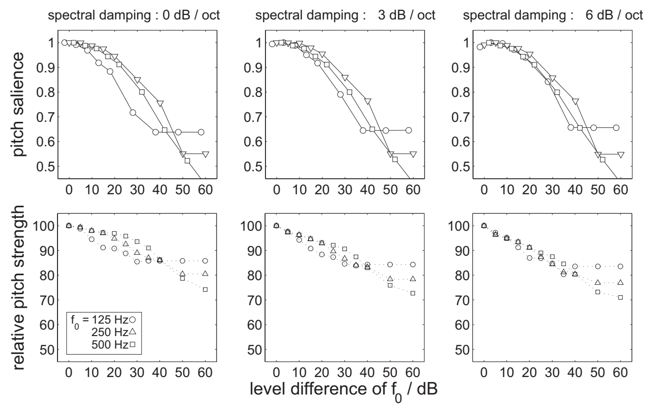

Figure 3: *Results of the algorithm for pitch salience (above) and of the calculations for pitch strength (below).*

Calculating Pitch Strength based on an algorithm for pitch salience

A psychoacoustic measure in many ways similar but also different to the pitch strength is the so called pitch salience. This measure has been established earlier to describe the perceivability of single tonal components within a sound. These tonal components are characteristic to describe a sound using the so-called parttone-time-pattern. Features like parttones can be used to describe tonal sounds and also data reduction and feature extraction (see [6] and [5]). To calculate pitch salience, an algorithm was introduced by Terhardt [2].
Accoding to the theories on residual and virtual pitch, the overall pitch of a sound is determined by the interaction of the perceivable pitches. Thus it seems plausible to try to describe the pitch strength based on the values for pitch salience. The basic outline of a possible algorithm is shown in figure 3.
It appears that pitch salience and pitch strength are two different measures especially when looking at the pitch perception of harmonic complex tones. While pitch salience increases with the number of harmonic parttones, the pitch strength decreases. So pitch salience describes the possibility to tune to a certain sound while pitch strength describes how pure a tone is perceived.
For the signals used in the experiments shown in figure 2 the calculated values of pitch salience are shown in figure 3 in the top row. It shows that these values principally follow the behaviour of the experimental data, but that the decrease of pitch salience is much stronger than the decrease of pitch strength.
By introducing an exponent of 0.55 the data could be adjusted so that the pitch strength can be described by the following equation:

$$pitchstrength \approx pitchsalience^{0.55}$$

The influence of other weighting functions is of minor importance for the presented sound configurations. Their influence is higher when simulating the pitch strength of harmonic complex tones e.g. with varying numbers of fundamentals. Corresponding data will be shown in future publications.

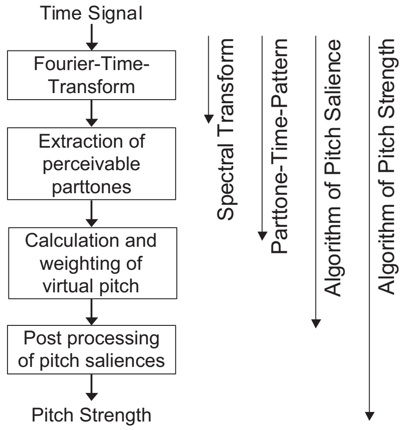

Figure 4: *Outline of an algorithm for the calculation of pitch strength. The algorithm principally uses the algorithm of pitch salience with additional post-processing.*

Conclusion

In the present study, the pitch strength of harmonic complex tones with varying level of the fundamental is investigated. As expected, for a certain damping, the pitch perception is dominated by the virtual pitch and pitch strength reaches at the value for virtual pitch.
An algorithm based on pitch salience is introduced using some post processing on the calculated values of pitch salience to simulate the data of pitch strength. For the presented sounds only minor changes need to be made to principally follow the experimental data.
The outlined algorithm of pitch strength will be adjusted in detail and will be presented in future work.

Acknowledgments

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