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Measurement of Tinnitus Using Interactive Evolutionary Computation

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1. Introduction

It is well-known that high intensity level and continuous environment noise (e.g., noise in a concrete factory) induce a high-frequency hearing loss which frequently accompanies "ringing" in the ear. The abnormal auditory perception is called tinnitus, defined as "the sensation of sound without external stimulation (ANSI, 1969)." As tinnitus is a subjective experience, it is hard for other people to know the exact characteristics of tinnitus sounds. Since Fowler (1941) developed a method to match pitch and loudness of the perceived tinnitus sound, many studies have been reported that used an audiometer to measure the acoustic characteristics of the tinnitus. However, it has been very difficult to investigate the fine characteristics of tinnitus sounds because an audiometer has limitations in the number of pure tone frequencies and the bandwidths of noise. Hazel (1981) attempted to match the perceived tinnitus sound in 200 patients using a music synthesizer. Although near matches were achieved, it was never possible to imitate the tinnitus sound. In the present study, we propose a new tinnitus test based on interactive evolutionary computation (IEC). This method optimizes the process of automatic test-tone selection for probing the acoustic characteristics of the patient's tinnitus. The method is based on the patient's evaluation. The utility of the tinnitus test using IEC was investigated for normal hearing subjects with a monaural, pseudo-tinnitus tone.

2. Tinnitus test using interactive evolutionary computation (IEC)

IEC is an optimization method that adopts evolutionary computation (EC) among system optimization that is based on subjective human evaluation (Takagi, 2001). In this study, the IEC-method employs genetic algorithms (GAs). The GAs are used to measure tinnitus sound as follows. First, twenty pure tones randomized with regard to frequency range and sensation level were generated as the initial group of test tones. Second, the similarity between each tone of the initial group and the subject's tinnitus tonality was scored from one (not similar) to five (similar) by the subject. Third, the higher scored tones were selected as dominant genes in the IEC and were crossed-over with each other to produce a new group of twenty test tones. A few test tones were generated with a low probability regardless of their similarity as mutant. The process (steps 1-3) was repeated five times. Finally, the highest scored tone in the fifth repetition (generation) was selected as tinnitus test-tone.

The developed apparatus had two kinds of signals for sinusoidal and noise waveforms. The center-frequency step for each tone was 1/24 octave, with a bandwidth of 1/64 octave. The cut-off frequency for the bandwidth was set at 1/12 octave. The test tone was presented as sensation level (SL) after measuring the thresholds (dB SPL) from 0.125 kHz to 12 kHz.

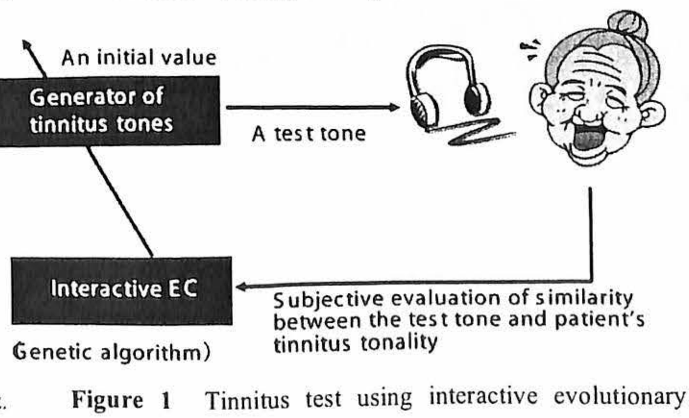


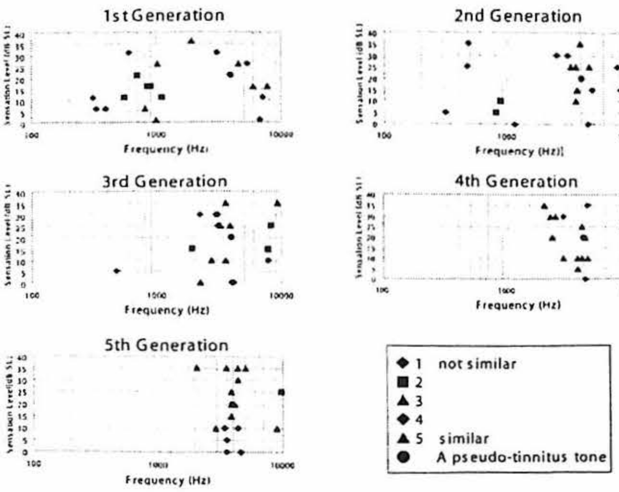
Figure 1 Tinnitus test using interactive evolutionary computation

3. Materials and Methods

An experiment to confirm the accuracy of the tinnitus test using the IEC was carried out for ten college students with normal hearing. A pseudo-tinnitus tone, a pure tone with a frequency of 4,000 Hz and an intensity of 20 dB sensation level (SL), was used as a test tone. The pseudo-tinnitus tone had a duration of 2 sec and was presented monaurally, to the right ear of a subject. The test tone had a duration of 2 sec and was presented to the same ear as the test tone after 1 sec. The frequency range of the test tone varied from 306 Hz to 11,986 Hz, in steps of 1/24 octave. The output level of the test tone was varied from 0 to 35 dB (SL) by steps of 5 dB. Subjects were instructed compare the test tone to the pseudo-tinnitus tone on a scale from "1 (not similar)" to "5 (similar)".

4. Results

Typical results of each IEC-generation obtained from a subject are shown in Figure 2. The black circles in Figure 2 denote the pseudo-tinnitus tone. In the 1st and 2nd generations, the test tones were widely distributed both with regard to the frequency (Hz) and sensation level (dB SL). In the 4th and 5th generations, however, the test tones were observed around the frequency of the pseudo-tinnitus tone. On the other hand, the measured sensation levels did not match the level of the pseudo-tinnitus tone. In Figure 3, the highest scores from the ten subjects are plotted. The frequencies of the high scores were very close to the frequency of the pseudo-tinnitus tone (4,000 Hz). The average frequency of the highest score among the subjects was 3,849 Hz. An octave confusion, which frequency was far more than 1 octave from the pseudo-tinnitus tone, was observed at a near frequency of 1,000 Hz for one subject.



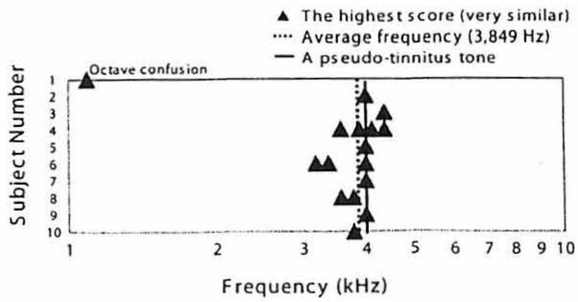


Figure 2 Typical results obtained from a subject using the IEC-method

Figure 3 Highest score distribution from ten subjects in the 5th generation

4. Conclusion

The highest scored tone in the fifth generation was very close to the frequency of the pseudo-tinnitus tone. For sensation level, however, the highest scored tone showed a poor convergence. The results suggest that the tonality of tinnitus sound in patients may be mainly judged from frequency, rather than intensity. Instead of a pure tone, further study with a noise with various band widths is needed in order to develop the IEC procedure into a clinical test.

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