Musical Instruments Signal Analysis and Recognition Using Fractal Features

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1. Outline - Contributions
- Analyze musical signals using the theory of fractal model the geometrical complexity of the waveform via the fractal dimension
- Novel approach for the analysis of the structure of musical instruments signals at multiple levels
- Time analysis for the distinction of different instrument classes and exploration of the differences between the attack and steady state of the tones
- Goal: Feature configurations focusing at multiple scales and the statistical self-similarity of the signals that offer a modest improvement to the performance of a recognition task

2. Multiscale Fractal Dimension (MFD)
- Short-time fractal dimension D: approximately quantifies the degree of turbulence.
- Multiscale fractal dimension profile MFD extracts the multiscale complexity of the waveform, thus the degree of fragmentation.
- Algorithm: based on multiscale nonlinear operators of morphological filtering that creates geometrical covers around the graph of the signal

3. MFD on attack & steady state
1st Step: Processing of the input signal

2nd Step: Analysis Using Multiscale Fractal Exponents

MFD

Calculate the short time MFDs of the tones, 30 ms segments, updated every 15 ms
- Sampling Frequency: 44.1KHz
- MFDs are analyzed for discrete scales \( s = 1, \ldots, 150 \)
- Time scales \( s \) from 144.1 to 3 ms

3rd Step: Feature set configuration

Feature sets
- 13 MFD(log-squared) features \( \text{MFD}_{1:15} \)
- 6 PCA components \( \text{MFDPCs} \)

4. Analysis cases

Average MFDs on Attack

- Estimated for 7 instruments
- Similar as for the steady state
- Eight D for small scales \( s \), and more fragmentation.
- Increased value of \( D \) by 1.6
- Clear distinction of \( D \) among some of the analyzed instruments.
- The instruments’ specific MFDs beholds the shape observed for the specific octave.

5. Experimental Evaluation

4th Step: Recognition Experiments

- 143 notes, 7 instruments
- 5 feature sets
- \( \text{MFDPCs} \)
- \( \text{MFD}_{1:15} \)
- \( \text{MFDPCs} + \text{MFD}_{1:15} \)
- \( \text{MFD}_{1:15} \) and \( \text{MFDPCs} \) features
- Classification methods:

Results
- Double Bass, Bassoon & Trumpet best recognized
- Low discriminability between Bb Clarinet and Horn
- Enhanced discriminability for Bassoon, Bb Clarinet and Horn
- Decreased for Cello & Flute

6. More examples

Acknowledgments

References

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