Title	非負値行列因子分解を用いたピ　アノ音の個体差分析に関する研究
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Citation	
Issue Date	2014-03
Type	Thesis or Dissertation
Text version	author
URL	http://hdl.handle.net/10119/12053
Rights	
Description	Supervisor:赤木正人，情報科学研究科，修士

Study on Analyzing Individuality of Piano Sounds Using Non-negative Matrix Factorization

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February 12, 2014

Keywords: piano, individuality, non-negative matrix factorization.

Recently, people who are not familiar with composing music can easily compose music by themselves beacause of development of computers and softwares. Especially, people are not required to prepare hardware effectors such as an equalizer and a dynamic range compression by development of digital audio workstation (DAW) which is anelectronic built-in system for recording, editting and mixing. In computer music, sound produnction softwares (e.g. MIDI sound source) are widely used. However, the softwares only provide typical musical instrument sounds. For this reason, people cannot use musical instrument sound with individuality with such softwares. In order to use musical instrument sounds with individuality instead of sound production softwares, huge single tone databases or playing musical instruments are required. Such databases are expensive and complicated to be constructed. Furthermore, it is hard for beginners to play musical instruments immediately. Therefore, it is difficult to use instrument sounds with individuality for composing music.

There have been researches investigating physical models of musical instruments considering sound production mechanisms. Nevertheless, in the case of pianos, no model is successful with pianos sound because it is difficult to express a desirable piano sound due to its complexity. Yamaya *et al.* found that individuality of piano sounds is included in their harmonic structures and waveforms by analyzing the relationship between individuality of pianos and player's impression. However, they only indicated the attack part of piano sounds, and other parts were not considered. Moreover, Lee *et al.* indicated the harmonic structures change their shapes in time. Thus, it is insufficient to analyze individuality of a part of piano sounds.

This work aims to study individuality of piano sounds by analyzing their harmonic structure and temporal variation correspondingly. To do this analysis, Non-negative Matrix Factorization (NMF) is used as an analysis method. NMF can decompose one sound spectrogram into two non negative matrices. One of them called 'basis matrix' expresses spectra of K sources. The other called 'activation matrix' expresses variation of each vector in basis matrix. NMF can also decompose a piano sound spectrogram into common components of piano sounds and its individuality by fixing parts of basis matrix to common components of piano sounds. To analyze individuality of piano sounds, log power spectrograms are used as input signal of NMF by considering sound production mechanism of pianos.

To determine number of basis K in NMF, analyzing piano sounds using NMF with increasing number of K from one to five was done. To evaluate K, signal to distortion ratio (SDR) was also calculated. Though number of basis is increased, SDR was not so improved when K is more than three. When the number of bases K is more than four, the results of analysis were not corresponded to sound production mechanism of pianos. However, the results of analysis were divided into contour of stationary part, attack part and attenuation part when K is three. It is thought that the stationary part was corresponded to effects of sound board, and attack part was corresponded to noises which were occured when the piano key was hit and strings were striken by a hammer. The attenuation part was corresponded to 'double decay' of strings. For these result, it is appropriate to analyze individuality of piano sounds when the number of bases K is three. After determination of the number of K, NMF analyses with fixing parts of basis matrix to common components of piano sounds were done to reveal individuality of piano sounds. These results show that harmonic structure of resonance of sound board and the second decay of strings' vibrations were quite different among piano sounds. These component were also appeared as individuality of piano sounds and had the influence of the difference in sound production mechanism.

Moreover, the temporal variation in atteauation part is quite different between MIDI sound source and real piano sounds. MIDI sound source cannot express 'double decay' and influence of damper. In harmonic structure, though there were low peak caused by striking hammer in real sounds, there were no effect of striking hammer in MIDI sound sources. NMF analysis can also show these differences.

In this study, the individuality of piano sounds is analyzed with log power spectrogram by NMF. This method can divided input signal into each component if each component can be regarded as a series of filters. Therefore, if the components of other musical instruments are matched to this condition, individuality of them will be also appeard.

In addition, by swapping activation vector of MIDI sound source for that of real piano sounds, MIDI sound source can be transformed its timbre by resynthesizing waveforms through resynthesis of log power spectrogram. Therefore, these analysis results are expected for using timbre transformation and performance rendering.