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Automatic Recognition of Beatboxing Sounds using a Hidden Markov Model

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*Abstract*— Beatboxing or vocal percussion is a form of music that, despite its prominence, has not been studied extensively in Music Information Retrieval (MIR) research. This paper proposes a solution to the problem of automatic transcription for beatboxing. A Hidden Markov Model is used to predict the types of sound present in a beatboxing recording, and onset detection is used to determine the locations of the sounds in the signal.

# Introduction

## A. Motivation

Beatboxing can be defined as the art of vocal percussion, or mimicking real drum machines with the human mouth and voice. Beatboxing performances can be done solo or with a group of singers, like in a cappella music. Due to an inherent dependence on physical features (how the human mouth is shaped) and subjective interpretation (how a drum sound is translated to a vocal sound by each beatboxer), beatboxing sounds tend to vary significantly across individual performers. Despite this lack of consistency, most beatboxing sounds across performers can be loosely recognized as standard drum sounds (e.g. kicks, snares, hi-hats, among others). Therefore, it is possible to characterize beatboxing sounds as standard drum sounds, which is what this paper explores.

The research presented in this paper could lead to tools for beatboxers to record and transcribe other beatboxers’ performances.

## B. Problem Statement

Given an audio recording of a solo beatboxing performance, design a system that recognizes the percussion sounds (using a pre-learned set of 10 percussion sounds) and identifies their onset locations in the recording.

# System Design

The overall system requirements are: it must take in an input audio recording (of beatboxing) as a query, and produce an output list that includes the label and time of onset for every percussion sound in the recording.

## A. Hidden Markov Model

The proposed approach for beatboxing sound recognition is a Hidden Markov Model (HMM). The overall system is shown below.

The HMM design includes observations, states and a model. In this case, the observations are sections of the input audio signal (or query) that capture each individual sound. There are 10 distinct states that correspond to the 10 pre-defined set of percussion sounds. Finally, the model is a multivariate normal probability distribution that can be used to estimate the hidden state.

## B. Percussion Dictionary

The HMM has 10 distinct states that correspond to sounds in the percussion dictionary. The percussion dictionary was defined from a set of typical Western drum sounds, using Standard Beatboxing Notation (SBN).

1. Percussion Dictionary

| Percussion Sound | Standard Beatboxing Notation |
| --- | --- |
| Kick | B |
| Snare 1 | Pf |
| Snare 2 | Pch |
| Snare 3 | K |
| Snare 4 | ^Ksht |
| Snare roll | rrh |
| Closed hi-hat | t |
| Open hi-hat/crash/cymbal | ts |
| Rimshot | k |
| Lip Oscillation | BB |

## C. Obtaining Observations

Given the input audio query, the system obtains an array of observations and calculates feature vectors for each observation. The goal of this step is to isolate each sound (in the samples domain) made by the beatboxer and summarize its content in a feature vector. First, the onset locations in the query are calculated. Then, the tempo of the query is estimated. The tempo is used to calculate the window size of the observation, i.e. the number of samples after the onset that are recorded in the observation. The window size is calculated to be one eighth measure long. Figure\_\_ shows an example of an observation, obtained from a longer recording of a beatboxing recording.

After obtaining an array of such observations from the input query, the system calculates feature vectors for each observation. The feature vector contains 8 parameters that describe the observation sound: attack, release, sustain, decay, mean amplitude, maximum intensity value on a spectrogram of the sound, along with the frame index and frequency index of the maximum. These 8 parameters were chosen after initial data exploration – it was clear that the ADSR envelope would be an effective way of characterizing each percussion sound. Figures \_\_\_ show examples of ADSR envelopes for a kick, snare…

## D. Training Model

The model is trained from recordings of 6 different beatboxers making each of the 10 percussion sounds 4 times (i.e. a total of 240 sound observations). Features vectors are calculated for each of the 240 sounds. By combining the known ground truth with the feature vectors, mean and covariance parameters can be calculated for each percussion sound. Therefore, a multivariate normal distribution is obtained for each state, which is then used as the model for the HMM.

## E. Estimating States

Given a model and an array of observations, the system constructs a pairwise similarity matrix of size (10, N) where N is the number of observations in the array. The pairwise similarity matrix value at index (i, j) specifies the log of the conditional pdf value of observing the j-th feature vector given that the percussion sound was of type i. Once this matrix is constructed, the maximum probability state is picked in each column as the estimated hidden state.

## F. Key Assumptions

This system approaches the problem statement using a few assumptions that are worth noting:

* There is only one sound per eighth measure of a beatboxing recording.
* The beatboxing recording has constant tempo.
* The transition matrix for the HMM is constant, to avoid biases in the sound

# Data Collection

## A. Recording Procedure

The recording procedure involves 10 recordings, as described below:

* One recording at 120 BPM with each sound in the percussion dictionary performed 4 times (for model training)
* Three recordings of beat pattern A at 80/100/140 BPM
* Three recordings of beat pattern B at 80/100/140 BPM
* Three recordings of pseudo-random beats (the beatboxer chooses from a set of three) or random beats (the beatboxer makes up their own beat)

The complete beat patterns are available in the Appendix. The recording procedure was designed to get a spread of data (known and unknown tempo, known and unknown beat patterns). The first recording was specifically designed for model training.

## B. Status

The final dataset included recordings from 6 different beatboxers, i.e. 60 recordings in total with each recording containing 8-16 beats.

# Results

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## A. Evaluation Metric

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract.

## B. Results

* Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as “3.5-inch disk drive”.
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# Discussion

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## C. Future work

Get more data

# Conclusion

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Appendix

Beat patterns:

Acknowledgment

The team thanks Professor TJ Tsai for his guidance throughout the semester and during the project. The team also acknowledges the time and effort put in by the six beatboxers from the Claremont Colleges a cappella groups to record the test data.

References

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