[[1]](#footnote-1)

A Brief Review of Automatic Chord Recognition

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# ntroduction

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he Automatic Chord Recognition, is an important technology in the field of Music Information Retrieval. To explain the function of ACR, we need to first introduce the concept of chord. A chord in musicology, is defined as a set of simultaneous tone, usually more than three tones. If there are three tones in total, the chord is called a triad; if there are four tones, it is called a seventh chord. Due to the definition of musical tones, the multiple frequencies are defined as a same tone. For example, 440 Hz, and 880 Hz, is the same tone *A*. In a typical musical piece, the chord will change frequently, generally changes every few seconds. This changing of chords carries the emotion and progress of a musical piece, hence it is a very fundamental concept in music.

The difficulty of ACR comes from the aspect of acoustics, musical instruments, and musicology.

In the field of acoustics, we found that the harmonic component of instruments in complex. We recognize the pitch of a tone through its fundamental frequency, while retrieve the timbre from other harmonic components. These overtones are unique for different instruments, different playing techniques, and different recording conditions, which makes it difficult to extract the fundamental frequencies.

Since many music pieces are played by multiple instruments it also increases the difficulty. For example, the three tones of a chord might be played by three different instruments; It is common that the lowest tone, called root tone, is played by a bass; a middle tone played by piano, and the highest tone played by violin or trumpet.

The composition of music also increases this difficulty. Although defined as simultaneously played tones, the actual chord might be played separately, and still be recognized as an identical chord. Another problem is that there might be out-of-chord tones in a musical piece. For example, the background piano plays a C major chord, consists of C, E and G; However, a singer might be singing a melody of A, B, D, C.

In this brief review, I will introduce two dominant methods in Automatic Chord Recognition and some new methods. First one is the oldest method called Pitch Class Profile (Fujishima, 1999)[1]. Another enhanced method, which borrows the thought of Automatic Speech Recognition, is applying Hidden Markov Model (HMM), first implemented 2003. (A. Sheh and D. P. Ellis)[2]. Further enhancements, including Enhanced Pitch Profile (EPCP), (K. Lee, 2006)[3], Convolutional Neural Networks (CNN) [4], will be briefly introduced as well.

# Pitch Class Profile

Pitch Class Profile is a specific feature, used in Automatic Chord Recognition. Perception of musical pitch has two dimensions: *height* and *chroma.* Pitch height moves vertically in octaves, telling which octave a note belongs to. On the other hand, chroma tells where it stands in relation to others within an octave. The Pitch Class Profile (also called *chromagram*), is a 12-dimentional vector representation of a chroma, which represents the relative intensity in each of twelve semitons in a chromatic scale. Since a chord is composed of a set of tones, and its label is only determined by the position of these tones in a chroma, regardless of their heights, *chromagram* seems to be an identical feature to represent a musical chord.

In order to obtain the PCP, take procedures as following:

1. For input signal , compute the DFT
2. Compute constant-Q transform , which is a logarithmic compression. It tunes the spectrum to the resolution of human ear. For band , the frequency is , where *B* is manually set, usually 12, 24 or 36.
3. Compute the PCP: *b* is the PCP index from 1 to *B*.

TABLE I

DNS Poisoning status

|  |  |  |
| --- | --- | --- |
| ISP name | Website | Poisoned or not |
| 广东电信 | Google.com | Not poisoned |
| 广东电信 | Twitter.com | Poisoned |
| 广东电信 | Fake address | Not poisoned (Non-exist domain) |
| 济南联通 | Google.com | Poisoned |
| 济南联通 | Twitter.com | Poisoned |
| 济南联通 | Fake address | Poisoned (Fake doain) |
| 8.8.8.8 | Google.com | Poisoned |
| 8.8.8.8 | Twitter.com | Poisoned |
| 8.8.8.8 | Fake address | Not poisoned (Non-exist domain) |
|  |  |  |

# Result

## Types of Graphics

The following list outlines the different types of graphics published in IEEE journals. They are categorized based on their construction, and use of color / shades of gray:

# Conclusion

References

*Basic format for journals (when available online):*

J. K. Author, “Name of paper,” *Abbrev. Title of Periodical*, vol. *x*, no. *x*, pp. *xxx-xxx*, Abbrev. Month, year. Accessed on: Month, Day, year, DOI: 10.1109.*XXX*.123456, [Online].

*Examples:*

1. T. Fujishima, “Realtime chord recognition of musical sound: a system using common lisp music,” In *Proc. ICMC*, 1999
2. A. Sheh and D. P. Ellis, “Chord segmentation and recognition using EM-trained hidden Markov models,” in *Proceedings of the International Symposium on Music Information Retrieval,* Baltimore, MD, 2003.
3. K. Lee, “Automatic chord recognition using enhanced pitch class profile,” in *Proceedings of the International Computer Music Conference*, New Orleans, USA, 2006.
4. E. J. Humphrey and J. P. Bello. Rethinking automatic chord recognition with convolutional neural networks. In *ICMLA 11*, volume 2, pages 357–362, 2012.

1. [↑](#footnote-ref-1)