Investigation Research about Improvement of Robustness against Distortion of Query on High-Speed Search from Large-Scale Database of Music Fingerprints

Masahiro Fukuda(1310203)

School of Information Science,
Japan Advanced Institute of Science and Technology

August 6th, 2015

Keywords: FPGA, Music Fingerprint, Locality Sensitive Hashing, Database of Ten Million Musics.

1 Introduction

The recent internet is a hotbed of unauthorized copying whereas it provides the field for active music distribution. Availability of music on the internet is attractive, but it is cramped that we must be always aware of the copyright law. In that situation, an easy and law-abiding music sharing system is proposed, which can automatically provide the license and billing information to the receiver when the music data is communicated by an e-mail or through P2P.

In order to put this music sharing system to practical use, a kind of embedded system is necessary, which is capable of high-speed and high-accuracy searching in a networking equipment. However the supporting data transfer rate of networking equipments continues to be faster year after year, and then it is difficult to do real-time processing of searching. When storing the database (DB) of 10 million musics which occupies over 10GB, the use of low-speed HDD or SSD should be avoided.

The purpose of this research is to realize the music searching from the DB of over 10 million musics with high-speed and high-accuracy as an embedded system.

2 Music Fingerprint and Related Works

One of the most important technology for high-speed music searching is fingerprinting. It is the essential technology for the high-speed music searching that is assumed as an embedded system because of the capacity of reducing the number of times of comparison process upon searching,

There are various difficulties in searching fingerprints in a networking equipment. They are roughly divided into five, that is “analysis of communication protocol,” “conversion into PCM data,” “fingerprint generation,” “fingerprint search,” “sending license and billing information,”

but in this paper we focus on fingerprint search among them in view of the necessity of improvement and the technological difficulty.

About fingerprint search, Yang's method which is one of the previous researches is suitable for high-speed fingerprint searching as an embedded system. One of Yang's two contributions is the hardware accelerator for the Hamming distance calculation and the other is the searching algorithm which is named Staged LSH. In the case of basic LSH, after the hash search, the system determines whether the fingerprint is from same music or not by calculating the Hamming distance of 4096-bit fingerprint. Staged LSH further decreases the number of times of comparison process by calculating the Hamming distance by much fewer bits before 4096-bit fingerprint.

Although Staged LSH has achieved a certain degree of success on speed-up of music fingerprint searching, the experiment with over 300 musics has not been done due to the large size of the fingerprint DB and hash table. Another problem is that Staged LSH does the hash search and so it is sensitive to the distortion (bit errors) of a fingerprint caused by a lossy compression of music data.

3 Implementation of Large-Scale Music Fingerprint Search System by Hierarchical Staged LSH

Because the target is an embedded system and the high-speed is important on it, FPGA is chose to implement music fingerprint searching in this research. The goal of the searching speed is within 80 microseconds per one request of search.

One of the two proposed methods is Staged LSH which uses two kinds of memories. The two mean High-Speed Memory, which is a DRAM through DDR3 embedded in the FPGA board, and Large-Capacity Memory, which is also a DRAM accessed through PCIe. The theoretical performance is 12.8 GB/s and 8 GB/s, respectively. Furthermore, we adopted Hierarchical Staged LSH algorithm, which can complete searching fingerprints which are highly frequently requested to search only with High-Speed Memory.

The other proposed method is named Neighbor LSH Search. The simple hash search fails to search even if there is one bit error in hash value. The hash search by LSH can adjust the number of bits of output, so we can increase the probability of the successful hash search simply by reducing the number of bits, but the problem of doing so is that the speed of the search drops because the probability of the collision increases. Then we propose Neighbor LSH Search which allows errors of up to a few bits in hash value.

The above proposed methods were implemented by FPGA. Large-Capacity Memory reads data from the DRAM in a desktop PC through PCIe, but the desktop PC is used only as Large-Capacity Memory, and the process of music searching is done not by CPU but by FPGA.

4 Evaluation Experiments

The experiments for evaluating each effect of Hierarchical Staged LSH and Neighbor LSH search were carried out.

First we evaluated Hierarchical Staged LSH using the fingerprint DB equivalent to 10 million musics generated by random number. It may depend on the capacity of High-Speed Memory and the speed of Large-Capacity Memory, but we got 4.3 times improvement about the search speed at most in this experiment. As for the accuracy, there was no degradation. In the first place Yang's research was the experiment based on up to 300 musics, and we could extend it to 10 million musics.

Next we evaluated the evaluation of Neighbor LSH Search. On the experiment using the same 10 million random number fingerprint DB, we could improve the search speed 8.9 times faster at most while maintaining the accuracy against the bit error rate of up to 25 %. This is achieved by adjusting the number of bits of hash from 13 to 20 and tolerating up to 1 bit error of the hash value.

Finally we evaluated the combination of Hierarchical Staged LSH and Neighbor LSH Search. We could improve the search speed 27.0 times faster at most while maintaining the accuracy against the bit error rate of up to 25 % compared to the case of both proposed method were disabled. As a result, the search speed was faster than a router of 1Gbps.

The main future work is a method to dynamically exchange data between two kinds of memories and to efficiently distinguish similar fingerprints.