Abstract

This contribution uses nested lattice codes to improve fundamental hash functions for particular image retrieval systems and a promising class of similarity search applications. Our proposed content-based image hash function takes advantages of SURF for feature extraction and lattices for quantizing feature vectors to hash values. The goal is to develop a lattice-based hashing scheme such that there is a proportional relationship between Euclidean distance and metric distances (Hamming distance or, as in this thesis, weighted Hamming distance and first difference distance) to increase the hash function's robustness. As a major result, our proposed two-dimensional nested lattice code reduces the normalized mean square error (NMSE) by 20% compared to two-dimensional Gray code.

In terms of similarity search, it has been established as an essential paradigm for a variety of applications, including information retrieval, data mining, multimedia database searching and machine learning. The similarity search problem is to find the object (e.g., image, sound, video, file) most similar to a given object in a set of objects, which are usually represented by a collection of real number feature vectors in Euclidean space. The most simple solution for comparison is sample-by-sample which is computationally slow. Our motivation is comparing data more efficiently by developing a lattice-based hashing scheme.

In terms of a particular image hashing system, content-based hash functions are widely used to index and protect data from distortion attacks that steal or alter data illegally. This method generates the hash value from the image features, then it is suitable for multimedia files indexing which should be able to tolerate some minor modifications. In addition, the content-based approach can be applied to image retrieval systems, such as multimedia database indexing which is simulated in the experiment section of this thesis.

A framework for the content-based hashing system includes feature extraction and quantization. First, the input signal is pre-processed to real feature vectors using signal processing techniques such as singular value decomposition (SVD), speeded up robust features (SURF), scale invariant feature transform(SIFT), Fourier transform and other signal processing operations. Then real feature vectors are converted to binary hash value using codes such as Gray code and Reed-Muller code or, as in this thesis, lattice code. In this research, we concentrate on improving the quantization step by using SURF and nested lattice codes.

Lattices are efficient structures for various geometric, coding and quantization problems. Lattice code has several advantages compared to a Gray code which is

widely used in quantization step. While a Gray code requires a scalar quantizer, lattices employ vector quantization. It is well-known that vector quantizers have lower quantization error than scalar quantizers; therefore, a lattice code is more suitable for quantization.

In summary, this thesis first proposed a weighted Hamming distance and first difference distance as new metrics versus Euclidean distance. The experiment result shows that our proposed metrics are better than traditional Hamming distance in terms of reflecting the similarity between vectors. Second, the Gray code is replaced by a lattice code, a nested lattice indexing scheme is proposed, and multi-dimensional nested lattices experiment. In results so far, the combination of two-dimensional nested lattice and first difference distance reduces the normalized mean square error (NMSE) by 20% compared to two-dimensional Gray code. Finally, to construct a complete content-based image hash function, we used SURF to extract feature vectors in the feature extraction step; then, using nested lattice code for quantization step. This image hash function takes the advantages of both SURF(a robust content-based feature extraction against distortions) and nested lattice (an efficient quantizing scheme).

Keywords: Nested lattice codes, nested lattice indexing, content-based, image hash functions.