

DCT-BASED DOWNSCALING EFFECTS ON COLOR AND TEXTURE-BASED IMAGE RETRIEVAL

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This paper evaluates the effects of downscaling in compressed domain on content-based image retrieval based on experimental studies. Several experimental databases are generated based on uncompressed ones using JPEG compression and DCT-scaling. Color and texture features are used in the retrieval queries, which constitute the base for the experiments. The query results are graded subjectively, and then the grades are used to obtain statistical values for evaluating the concrete effects. The evaluation results show that downscaling does not have significant impact on color-based retrieval in general, while it degrades texture-based retrieval performance significantly. The results also verify that querying uncompressed images in uncompressed databases gives the best color and texture-based retrieval performance. Querying compressed images in uncompressed and compressed databases yields similar color-based retrieval results for each scaling factor. On the other hand, querying compressed images in uncompressed databases drastically degrades the texture-based retrieval performance.

1. Introduction

Multimedia indexing and retrieval has been an active research area addressing the problems caused by rapid increase of digital audio/visual information during the recent decades. The studies started with simple techniques, and further extensive studies have led to more reliable indexing and retrieval schemes for large image and video databases. Various indexing and retrieval systems focusing on the contents of multimedia items have been proposed [1], [2], [3]. Although these content-based multimedia indexing and retrieval (CBMIR) systems have been fairly successful, researchers have faced several practical problems. Optimizing retrieval performance, improving reliability of retrieval and overcoming strict resource limitations are examples for such major problems.

Due to large space requirement of digital media databases, CBMIR systems have the tendency to deal with compressed data. Using compressed domain feature extraction algorithms, it is even possible to extract content information

directly from the compressed data. However, in certain cases lossy compression methods may degrade multimedia retrieval performance as presented in [4].

Another way for reducing image and video data size is downscaling the frame size. The so-called thumbnails have widely been used for displaying purposes in retrieval terminals [5]. Besides for such display purposes, downscaling may also be useful for overcoming large memory and disk space as well as high processing capability requirements, particularly in limited applications and devices, e.g. mobile devices. Downscaling may also have filtering effects on the visual data. On the other hand, downscaling methods may cause crucial information loss, which in turn degrades the retrieval performance.

The issues so far discussed constitute the main motivation for studying the effects of downscaling on image retrieval in this paper. The downscaling effects are evaluated via image retrieval experiments using the MUVIS CBMIR framework [1]. HSV and YUV color histograms [6], Gabor Wavelet Transform (GWT) [7] and Gray Level Co-occurrence Matrix (GLCM) [8] feature extraction methods are employed for image retrieval. Image scaling is achieved by DCT-based downscaling on JPEG compressed domain [10], [11].

The rest of the paper is organized as follows. Section-2 introduces the experimental setup and the framework, and briefly discusses the feature extraction algorithms employed. Section-3 presents the experimental results and the downscaling effects. Finally, Section-4 concludes the paper along with some future remarks.

2. Experimental Setup

2.1. Experimental Databases And Query Sets

Several digital uncompressed images were collected from various sources and the following image databases were created using the MUVIS applications for running the experiments:

- **Base Image Database:** It is a general-purpose database including 1594 uncompressed color images with various sizes (from 100x100 up to 1200x1000 pixels) and color bit depths (8-24 bits) in bitmap format. The images are mostly photographic and have various contents from sports to nature. This database is used only for color-based retrieval experiments.
- **Base Texture Image Database:** It is a constraint database including 1512 uncompressed gray-scale images with 166x166 pixels and 8 bits luminance depth in the bitmap format. Images contain textures of mainly 6 different rock classes as in [8], [9]. The database is used only for texture-based retrieval experiments.

Table 1: Experimental databases generated from each base image databases

| Database Properties | | Extracted Color Features | Database Properties | | Extracted Texture Features |
|-----------------------|----------------|------------------------------|-----------------------|----------------|---|
| Compression Quality / | Scaling factor | | Compression Quality / | Scaling factor | |
| 75% / 87% | 1 | HSV and YUV Color Histogram, | 75% / 87% | 1 | GWT, Orient: 4 Scale: 3 Side: 45 |
| | 2 | | | 2 | |
| | 4 | | | 4 | |
| | 8 | | | 8 | |
| 50% / 92% | 1 | Histogram BINS: | 50% / 92% | 1 | GLCM, Distances |
| | 2 | | | 2 | |
| | 4 | | | 4 | |
| | 8 | | | 8 | |
| 25% / 95% | 1 | 8 - 4 - 4 | 25% / 95% | 1 | 1 - 1 5 - 5 12 - 12 24 - 24 |
| | 2 | 8 - 8 - 8 | | 2 | |
| | 4 | 16 - 1 - 1 | | 4 | |
| | 8 | 1 - 1 - 16 | | 8 | |
| 10% / 98% | 1 | 1 - 16 - 1 | 10% / 98% | 1 | |
| | 2 | | | 2 | |
| | 4 | | | 4 | |
| | 8 | | | 8 | |

As shown in Table 1, 16 compressed and/or downscaled image databases are created from each base database using JPEG compression with DCT-based downscaling. Additionally, 15 uncompressed images are selected from each base database in order to prepare the experimental query sets. Similar to the created experimental databases, these images are compressed and/or downscaled to obtain 16 different querying sets. The uncompressed querying set is used for normalization of the subjective experiments. The normalization method is described in Section 3. The Euclidean distance is used as the similarity measurement for retrieval.

2.2. Subjective Evaluation of Queries

The evaluation of the retrieval performance is based on grades associated with each query result. The grading and evaluation system is a modified version of the one used in [4]. A group of non-expert people graded the first 12 retrieved items for each query. All grades were then used to obtain measures for evaluating the performance. The given grades are integer numbers within the range [0-5], which have corresponding subjective meanings.

Each of the 12 graded items has a weight associated with its rank. So-called *Performance Value (P)* is calculated using (Eq. 1). The average performance value within the evaluation group is called the *Query Performance Value (QP)* given in (Eq. 2). The *Overall Query Performance Value (OQP)* for an experimental case is defined as the mean of all *QP* values obtained from the

queries of the selected images. The retrieval performance evaluation is based on the OQP values that are divided by the corresponding normalization factor, which is described further in Section 3.

$$P = \sum_{i=1}^{12} G_i \cdot W_i , \quad (1)$$

where $G_i \in [0,5]$ is the given subjective grade, and $W_i = (13-i)$ is the weight for the item in the rank i .

$$QP = \frac{\sum_{j=1}^{NP} P_j}{NP} \quad \text{and} \quad OQP = \frac{\sum_{k=1}^N QP_k}{N} , \quad (2)$$

where N is the number of queries, and NP is the size of the evaluation group, which is 10 for these experiments.

3. Image Retrieval Experiments And Performance Results

Image retrieval experiments are handled separately for color and texture attributes. Both color and texture based experiments start with an initial step for normalization. Uncompressed query set is queried on the uncompressed image databases and the retrieval results are graded by the evaluation group. Each P value calculated is assumed to be the maximum that can be obtained for the corresponding image query graded by a member of the evaluation group. Thus, these P values are used for normalizing further P values that are obtained in the actual experiment cases for the corresponding image query and evaluating member.

The experiments are then divided into three different cases, each addressing one of the following content-base image retrieval (CBIR) system use cases in practice:

1. Use Case 1 considers a simple stand-alone CBIR system that has limitations for both queried images and image databases. For this system, both the query image and the image database are compressed and/or scaled with the same compression ratio/scaling factor.
2. Use Case 2 is dedicated for distributed CBIR systems, which have limitations only for the query (client) side but not for the image databases (which are assumed to reside on the server side). This system queries with a compressed and/or scaled image in an uncompressed image database.
3. Use Case 3 is also dedicated to distributed CBIR systems, which have again limitations in the query side. Besides, it also has fewer limitations for the image databases. Thus, in this case, the query image is compressed and/or scaled, and the image database is less compressed and unscaled.

The following sections present the retrieval experiment cases and their results.

3.1. Color-Based Image Retrieval Experiments

Color histogram is an efficient feature, which has been widely used by CBMIR systems. Among the color spaces, HSV is commonly considered for histogram due to its close relation with the human visual perception. YUV is also commonly used due to its practical benefits. Additionally, most JPEG codecs work in the YUV color space. These facts have led to employing HSV and YUV color histogram features for color-based image retrieval experiments. Table 1 presents the feature extraction parameters.

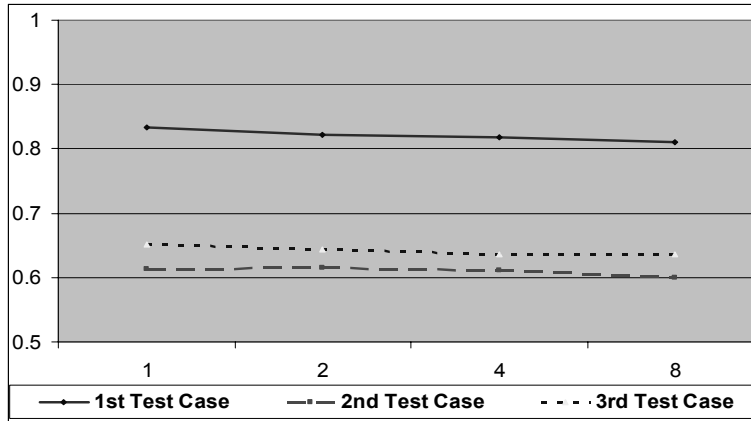


Figure 1: Overall color-based retrieval performance results

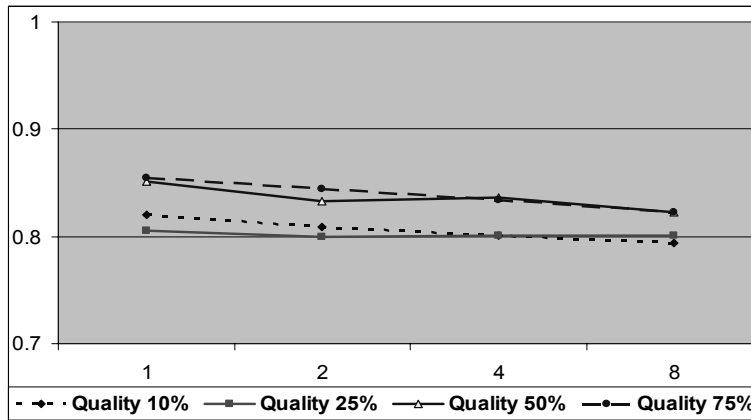


Figure 2: Color-based retrieval performance results for the first test case

In both figures, the horizontal axis represents the scaling factor while the vertical axis represents the normalized OQP values. The OQP values in the figures are between 80% and 90%, and they are stable in the horizontal direction for certain compression ratio. This means that scaling does not affect the performance significantly. The reason of this performance robustness to scaling can be explained with insignificant color information loss on the image pixels after DCT-based down scaling. It can also be seen from Figure 2 that OQP values are slightly lower for higher compression ratio at certain scaling factors. These differences for each scaling factor are also stable. The effects of compression are also studied in [4].

In the second test case 16 query sets are queried on uncompressed and unscaled database to simulate the second use case. The average OQP values for this test case are shown in Figure 1. In general, the performance in this test case is lower than the previous case. This degradation in performance is caused by using different compression ratio for query image and image database. The quantization step in the lossy compression may shift the color values for each pixel in the image; consequently the comparison based on color information yields worse performance. Even if the same image is used in the query and image database, retrieval performance does not need to be high. However, the horizontal stability of the OQP values in the figure shows that performance is still robust to scaling.

Finally in the third case, the 16 query sets are queried on 75% compressed and unscaled database. Figure 1 plots the concerning average OQP values calculated for the queries. Third case reveals similar results to the second case. Different compression ratios in query image and image database cause low performance, although they are slightly better than in the second case. Scaling does not affect the performance significantly as in the previous test cases.

3.2. Texture-Based Image Retrieval Experiments

Gabor Wavelet Transform and Gray Level Co-occurrence Matrix features are extracted for retrieval experiments. These two texture feature extraction methods are widely used for CBIR systems and readily available in the MUVIS framework. The feature extraction parameters are shown in Table 1.

Texture-based retrieval experiments are carried out with a similar approach to color-based retrieval experiments using the databases shown in Table 1 and the relevant query sets. The experiments start with the initial normalization step. Then, three similar test cases are applied considering the aforementioned use cases. However, querying compressed images on uncompressed database in the second case revealed totally irrelevant results, and thus the second use case is ignored. Figure 3 illustrates the results of first and third test cases and Figure 4 separately presents the results of the first test case for each compression quality

parameter. The horizontal and vertical axes in the figures represent the normalized OQP values and the scaling factors, respectively.

It is easily observed from the figures that increasing the scaling factor degrades the retrieval performance in general. Scaling modifies the spatial information of image pixels, and it in turn affects the performance since texture features depend on spatial information. This effect can also be explained particularly considering the texture feature extraction methods: Gabor functions have highly specific spatial frequency information. The center frequency of the filters and the frequency of sampling and quantization density should be adjusted to achieve a fair representation of the Gabor filters. Additionally, each entry in GLCM corresponds to the number of occurrences of the pixels in a certain neighborhood. Hence, both feature extraction methods can be easily affected by scaling.

In the first test case, satisfactory performance results (~70%) can be still obtained for higher scaling factors, while in the second case the performance degrades drastically up to 20%. As shown in Figure 4, compressing both query image and image database slightly affects the performance for certain scaling factor. However, second and third cases show that using different compression ratio affects the performance significantly. The reason of poor performance in these cases is the close relation of texture features to luminance values and the luminance value shifts caused by lossy compression.

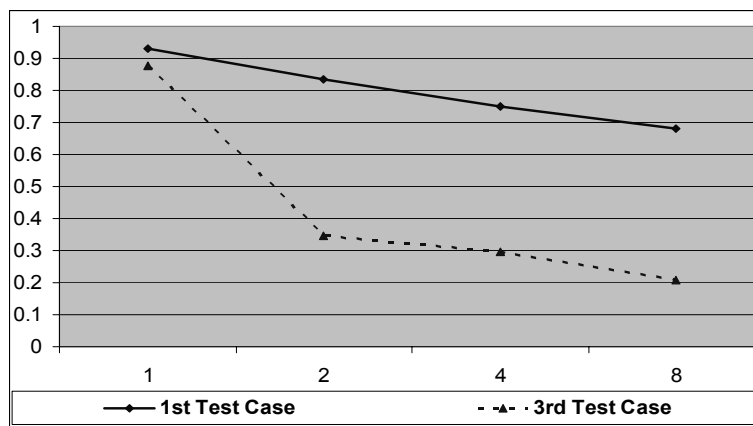


Figure 3: Overall texture-based retrieval performance results

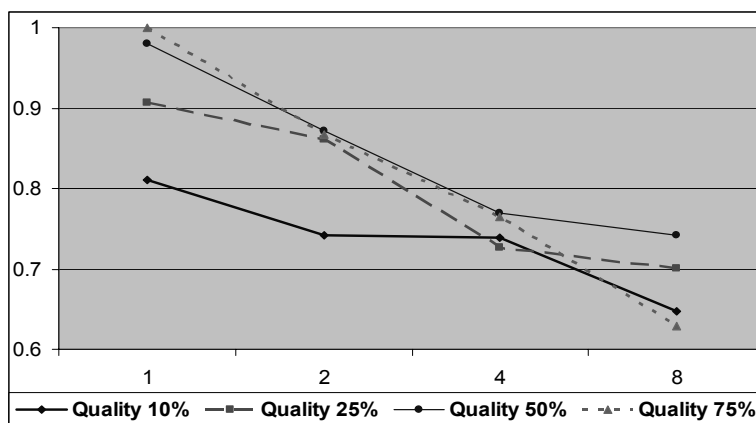


Figure 4: Texture-based retrieval performance results for the first test case

4. Conclusions and Future Work

Color and texture-based image retrieval experiments are performed in order to study the effects of scaling on retrieval performance. The retrieval performance is evaluated via subjective experiments based on human perception. DCT-based downscaling with JPEG compression is applied on the experimental image query sets and databases.

In color-based image retrieval experiments, scaling the query and database images does not affect the retrieval performance significantly for any of the test cases. The reason of this retrieval performance robustness can be explained with insignificant color information loss on the preserved image pixels after DCT-based downscaling. However, quantization in lossy compression may cause color shifts for each pixel in the image. This color information change is verified with the experiments, since querying images on the databases having the same compression parameters yields better results than querying on different databases. The retrieval performances obtained by querying the same images on uncompressed and compressed with a 75 % quality factor are similar. Considering the color features in general, 25%-50% quality parameters and scaling 1/8 achieves a satisfactory retrieval performance, where a satisfactory and efficient performance can be regarded as accomplishing the highest compression ratio and scaling factor without degrading retrieval performance significantly.

Previous studies show that texture-based retrieval performance, although slightly degrades, is more robust to compression. Additionally, maximum performance is achieved when the images and database are uncompressed. However, scaling tends to affect the texture-based retrieval performance

drastically. Queries lead to higher retrieval performance, when the query images and the database have the same scaling factor and the database is compressed. If the database is uncompressed while the query images are compressed, the query results are extremely unsuccessful and irrelevant. However, these retrieval experiments are performed on constrained databases. In this respect, such results cannot be generalized for overall texture-based image retrieval.

The practical benefits of using scaling and compression in CBIR systems are clearly visible, especially for limited and distributed systems. It might be possible to overcome various strict system requirements such as storage space and computational complexity. However, these studies should be extended using different features, scaling algorithms and feature extraction methods in order to get a reliable and more concrete picture on scaling effects on CBIR. Once the scaling effects are fully clarified, feature extraction methods could be improved for achieving more robust image retrieval. Furthermore, future work may also include studying the scaling effects on video sequences.

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