Information Hiding in Image Retrieval Systems

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Abstract—In this paper, a new approach for image retrieval system is proposed. By utilizing information hiding technique (steganography), the valuable image attributes can be hidden in an image content without degrading the image quality. In the proposed algorithm, to enhance both retrieval and steganographic performance, database images are compressed by using CHC-RIOT wavelet based coder. Consequently, the image attributes are invisibly embedded in CHC-RIOT compressed bitstream. Based on the simulation results, the proposed system not only shows the efficiency in hiding the attributes but also provides other advantages such as: (1) fast transmission of the retrieval image to the receiver, (2) allows further search based on the retrieved images, (3) no need to extract the attributes separately for other applications.

Index Terms—Attributes, Retrieval, Steganography, Wavelet based coder.

I. INTRODUCTION

According to the forthcoming MPEG-7 standard [1], the activities in image retrieval have been increasing. Strategies proposed for image retrieval systems basically approach content-based algorithms by utilizing the similarity between the images in the database and the query image. Normally, similarity is measured as attributes extracted from individual image in terms of color, shape, texture and spatial properties [2]. Utilizing the combination of this information, several retrieval systems have achieved promising performance [3,4,5]. Note that in these systems, after the retrieval, only the image data and not the attribute information is delivered to the user terminal. Unfortunately, since searching and browsing may not be the end tasks in many applications, the attribute information is useful for further implementations. Therefore, it is more practical, if the attribute information is transmitted along with the image data. However, transmitting the attributes to the end user requires additional transmission cost, data management and storage space. To overcome this problem, we utilize the concept of information hiding (steganography) to attach the image attributes in the image without increasing the image data size. Thus, this new steganographic approach increases the functional capability of retrieval systems, which allow an end user to perform further searches by directly using the embedded attributes in the retrieved image.

In sections 2 and 3, the overview of the proposed image retrieval system and the attribute extraction are described. Then, the CHC-RIOT (color homogenous connected-region interested ordered transmission) wavelet based coder used as a compression algorithm in retrieval database is introduced in section 4. In section 5, the exploration of information hiding in retrieval systems, which contain encoding and decoding processes, are explained. The simulation results are discussed in section 6. Finally section 7 ends with conclusions.

II. PROPOSED IMAGE RETRIEVAL SYSTEM

The proposed image retrieval is designed based on the general scheme described in [8]. As illustrated in Fig. 1, the system consists of two main phases, attributes generation phase and query phase. The attribute generation phase serves as a preprocessing operation for the image retrieval system. Its functions are to prepare, arrange, store and manage information in the database. This phase performs not only the general operations such as segmentation, feature extraction and data compression but also integrates the attributes (embedding process). First, each image contained in the database is segmented into groups of regions (objects) of interest such that their content features such as shape, color, texture and spatial properties are individually extracted. These attributes then are stored (embedded) in the image content by using the steganographic approach (see section 5). On the other hand, the query phase serves as the user interface. It consists of three processes, query generation, matching operation and content extraction. Since the attributes are embedded in the image data, the attribute extraction is required to decode the embedded attributes before performing the query process (Query-by-Example). In the query process, the similarities of attributes among query image and database images are measured. Only the images, which have similar characteristics as query image, are retrieved and transmitted to the end user.

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II. THE IMAGE ATTRIBUTE EXTRACTION

To extract attributes, first, a color image (generally represents in RGB color space) is converted to HSV format. Then, it is segmented into meaningful objects by the semi-automatic process using both brightness (V) and color information (H and S). Due to the ineffectiveness of automatic segmentation algorithms, the graphical interface is exploited to improve the segmentation results. After the image is segmented, the attributes such as color, shape, texture and spatial properties of each object are analyzed. These attributes represent the characteristics of the image which are needed for retrieval. Note that in the proposed system, not only using the content-based attributes (color, texture, shape, text and spatial information – Fig. 2) but also the text-based attribute is exploited. This text-based attribute provides a description of an image such as date, author and specific name (title). Note that, the color attributes are obtained by using back-projection method [4] and the texture attributes are extracted from the histogram of the overcomplete steerable pyramid [10]. The object bounding box [1] that represents the coarse shape description is used for shape attribute and the position of centroid of mass of an object in an image is used to provide the spatial information.

III. THE CHC-RIOT CODER

The CHC-RIOT wavelet coder is the color version of HC-RIOT proposed in [7] which is developed based on ZTE (Zerotree Entropy) [12] and SPIHT (Set Partitioning in Hierarchical Trees) [9] algorithms. Consequently, the CHC-RIOT inherits several properties such as the scalability, perceptual optimization, and spatial segmentation strategies. It compresses an image into multi-layer bitstreams, the base layer and enhancement layer bitstreams. The base layer bitstream provides a highly compressed fixed bit rate (modified version of ZTE algorithm) and the enhancement layer bitstream (modified version of SPIHT algorithm) provides the residual image information which enhances the image quality. As shown in Fig. 3, the structure of the CHC-RIOT consists of three processes: (1) Color converter, (2) Image encoder and (3) Image decoder.
IV. THE INFORMATION Hiding IN CHC-RIOT CODER

Generally, information hiding (steganography) is defined as the art and science of communicating in a covert fashion. Information hiding utilizes the digital signals (text, audio, image, video, etc.) as a carrier to hide extra information without degrading the quality of the host signal and creates no additional bit increase [6]. Even though the current approach of information hiding is to hide secret data for copyright protection (watermarking) [11], it is also useful in other applications, such as captioning in television, etc. In this section, the concept of information hiding is utilized to embed the attributes into the image.

A. Bit Requirement for Attributes

As the requirement of bits reserved for the attributes is an important issue, the capacity of the proposed embedding system must be sufficient to carry all necessary attributes. In Table 1, the average bit allocation required for the attributes is presented.

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Number of bits (per region)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>198</td>
</tr>
<tr>
<td>Texture</td>
<td>384</td>
</tr>
<tr>
<td>Shape</td>
<td>64</td>
</tr>
<tr>
<td>Spatial properties</td>
<td>64</td>
</tr>
<tr>
<td>Total per region</td>
<td>710</td>
</tr>
</tbody>
</table>

Note that an image can be segmented into 5-7 meaningful regions, on average.

Detail of the bit allocations (Table 1) for each attribute are:

- Color attribute: 166 color set (1 bit per color) and 1 power/energy (32 bits)
- Texture attribute: 1 standard deviation (16 bits) and 1 shape parameter (16 bits) for 3-level steerable pyramid with 4 orientation.
- Shape attribute: 2 coordinates x and y (64 bits)
- Spatial attribute: 2 coordinates x and y (64 bits)
- Text attribute: an option.

In the proposed embedding system, therefore, at least 5000 bits are reserved for embedding the image attributes.

B. The Information Hiding Process

The information hiding process is designed to embed/extract the image attributes in the CHC-RIOT domain. The steganographic encoder and decoder of the proposed retrieval system are illustrated in Figs. 6 and 7.

1) The steganographic encoder

To improve the invisibility, selection of the location to embed the attributes is taken into consideration. Based on the HVS, human eye is less sensitive to noise in edge and detail regions rather than in smooth areas, therefore embedding attributes in edge and detail regions allows more degradation (perceptually insensitive) in the image quality. In the steganographic encoder, the attributes are embedded in the edge and detail representing coefficients of enhancement layer bitstream. After the color conversion, each YUV color component is transformed by using discrete wavelet transform (DWT) (see section IV). In the base layer encoding, the wavelet coefficients are rearranged in the spatial orientation tree (SOT) structure and quantized by using ADZ/UTQ (Adaptive Deadzone / Uniform Threshold Quantization). Then, the WBC classifies the coarse subband wavelet coefficients into homogenous regions such as edge, detail and smooth regions. This classified information not only benefits the encoding process but also provides a valuable information to the embedding process. Furthermore, during the enhancement coding process, the visual mask threshold is used to determine whether the coefficient represents smooth or edge or detail areas. If the coefficient represents edge or detail region, then one bit of attribute sequence is substituted into the coefficient bit. Note that the embedded bits are stored in a separate bitstream for the simplicity of decoding and retrieving. Consequently, after the embedding process, the steganographic encoder outputs three types of bitstreams, base layer, enhancement layer and embedded bitstream (see Fig. 6).
2) The steganographic decoder

The steganographic decoder design is analogous to the encoder except that the operation is inverse to that of the encoder. As the embedded attribute bitstream is independently retained from other two (base layer and enhancement layer) bitstreams, the embedded attributes can be simply decrypted. This does not affect the processing time of the retrieval.

V. RESULTS AND DISCUSSION

The proposed steganographic retrieval system is designed based on three significant requirements: (1) invisibility, (2) detectability and (3) maximum amount (payload) of the embedded attributes. To evaluate the performance of the proposed system, public domain test images (Lena, Peppers, Jet etc.) of 512x512 RGB images with 8 bpp (each component) are used for evaluating the performance of embedding processes. In the simulation, test images are encoded at compression ratio of 10:1. The invisibility of the embedded attributes is evaluated by measuring the PSNR (Peak Signal to Noise Ratio). In Fig. 7, the effects on the image fidelities (only Y component) against several embedded attribute bits are compared. As the results, even though we increase the amount of embedded bits by 10 Kbits, the PSNR of the embedded Lena image (Y component) y changes approximately by only 1.5 dB.

a) no embedded bits (PSNR = 36.99 dB)

b) 5 Kbits embedded (PSNR = 35.54 dB)

c) 7 Kbits embedded (PSNR = 35.33 dB)

d) 10 Kbits embedded (PSNR = 35.24 dB)

Figure 7. The embedded images at different payloads

Figure 8 shows the PSNR of Lena image versus the amount of attribute bits which is embedded into each Y, U and V component. As the results show, even though a large amount of bits (larger than minimum bit requirement ~5000 bits) is embedded into the image (all cases), the PSNR is higher than 30 dB. This shows the less perceptual degradation in image quality.

Figure 8. PSNR of Lena image versus the amount of attribute bits embedded into each Y, U and V component

VI. CONCLUSIONS

In this paper, a new approach for image retrieval systems is proposed. Utilizing concepts of information hiding in the CHC-RIOT wavelet coder extends the ability of the retrieval systems by providing efficient use of the resources (attributes) after retrieval. While the proposed steganographic technique yields attributes that can be invisibly hidden in the image, it also allows reliable and fast decoding of the embedded attributes. Moreover, due to the multi-layer property of CHC-RIOT coder, the base layer can also be used as a thumbnail, which is transmitted to the user terminal for fast display. Once user makes a decision from the candidate thumbnails, only the selected enhancement layer bitstream is delivered thus providing faster data transmission. Consequently, it minimizes the storage space by eliminating the need for separate low-resolution (thumbnail) image and attributes.

VII. REFERENCES


