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Lossless Data Hiding and Data Extraction using Line Based Cubism

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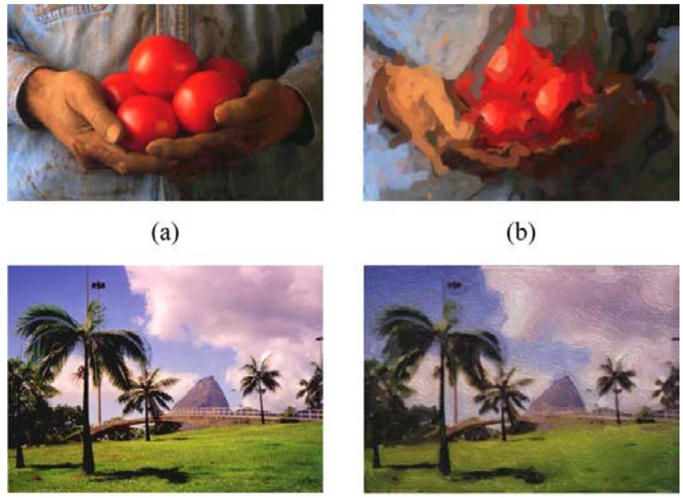
Abstract-- New type of computer art, called line-based cubism-like image, and a technique to create it automatically from a source image. The method finds line segments in the source image by Canny Edge Detection technique and Hough transform, combines nearby line segments, extends the remaining lines to the image boundaries, and re-color the created regions by their average colors, to create an abstract type of the original source image as the desired art image. Then, by utilizing the characteristics of the Cubism-like image creation process, a data hiding technique has been proposed. Based on the minimum color shifting of the values of 1, the technique embeds message data into the pixels of the regions of the generated art image while keeping the average region colors unchanged. Key Exchange algorithm is used to make sure the safety of the data. The data embedding process is proved to be lossless by theorems so that the cover image can be recovered perfectly after the embedded message data are extracted.

Index Terms—Cover image, line-based cubism-like image, stego image, Data Embedding, Extraction, Key Exchange.

INTRODUCTION

In recent years, the topic of automatic art image creation via the use of computers arouses interests of many people, and many methods have been proposed. Hertzmann surveys the ideas and algorithms of creating art images by stroke based rendering which is an automatic approach to creating non photorealistic imagery by the use of discrete elements like paint strokes and stipples. The common goal of creating these image styles is to make the generated art images look like some other types of images. For example, two images created by watercolour painting and oil painting in Hertzmann, respectively.

Mosaic image is also a type of computer art image about which many investigations have been conducted. Each mosaic image is composed of many small identical tiles, such as squares, circles, triangles, and so on. Different from conventional mosaic images which have tiles all arranged in a fixed orientation, Hausner created a type of tile mosaic image by placing tiles to follow the edges in the input image to make the created art image look smoother. Another important criterion for art image creation is to limit the number of strokes so that the resulting image looks like an abstract painting. Some paintings of the Cubism style are dominated by lines and regions, to show abstractly a characteristic of the Cubism art.



(a) (b) (c) (d)

On the other hand, Davis proposed the concept of signal rich art, and pointed out watermarking as a key component in achieving such art. Data hiding is a technique for watermarking and other applications, which embeds data imperceptibly into a cover image (or more generally, into cover media), so that people cannot perceive the existence of the hidden data in the resulting stego-image (or stego-media). Otori and Kuriyama hid data into texture images with the hidden data being robustly recoverable from images photographed from print media. It is also hoped that the characteristic of the art image creation process can be utilized effectively to carry out the data embedding work. This way of combining art image creation and data hiding, which may be called aesthetic data hiding, is a new idea of information hiding. Two criteria for designing data hiding techniques are imperceptibility of distortion in the stego-image due to data embedding and recoverability of the original cover image content from the stego-image. To achieve imperceptibility, a weakness of the human visual system in differentiating small color or greyscale differences is often utilized.

More specifically, in this study we hide message data in the automatically-generated Cubism-like image during the image creation process by shifting the colors of the pixels in the image regions slightly for the minimum amounts of ±while keeping the average colors of the regions unchanged. In this way, the original art style of the image with uniform regions may be kept. The color differences in the resulting image are difficult to be found by a hacker because the human visual system is weak in discriminating small color changes. Also, by constraining the numbers of the embedded binary values of 0's and 1's to keep the average region colors unchanged, the data embedding process can be reversed so

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that lossless recovery of the cover image from the stego-image can be achieved, as proved by theorems.

PROPOSED LINE-BASED CUBISM-LIKE IMAGE CREATION PROCESS

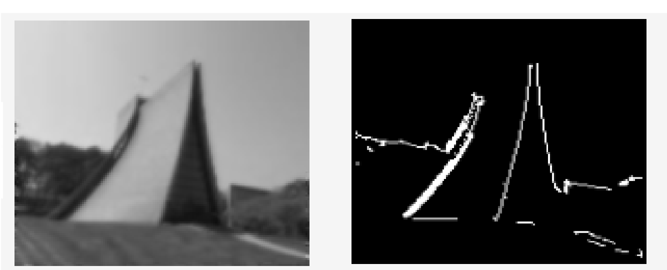
LINE-BASED CUBISM-LIKE IMAGE

Cubism artists transform a natural scene into geometric forms in paintings by breaking up, analyzing, and reassembling objects in the scene from multiple viewpoints. In addition, with the scene objects rearranged to intersect at random angles, each Cubism painting seems to be composed of intersecting lines and fragmented regions in an abstract style. The idea of the proposed art image creation technique is inspired by these concepts of the Cubism art. Specifically, there are two major stages in the proposed line based Cubism-like image generation process—prominent line extraction and region recoloring. In the first stage, at first we extract line segments from a given source image by edge detection and the Hough transform. Then, we conduct short line segment filtering and nearby line merging. In the second stage, at first we create regions in the image by extending the line segments to the image boundary to partition the image space. Then, we recolor the regions by the average region colors and whiten the boundaries of the regions.

STEPS IN LINE-BASED CUBISM

1.Upload a image

2.Apply Canny Edge detection to the image.



3.Apply Hough transform to find a list of line segments in the image.
4.Particular line segments are selected with the specified threshold values.

Two threshold values, namely, the minimum line segment length Lmin and the minimum line distance Dmin are used. They affect the generated Cubism-like image. We take one tenth of the image width as initial values of Lmin and Dmin. Therefore as a result yielded by the use of different set of values of the two thresholds. Specifically we use three values of 0.5/10, 1/10, 2/10 times the image width as the values for the threshold Lmin and Dmin. As a result of using three ratios we generate nine art images each correspond to one of the nine threshold combinations, and then user can choose any one from that choices.

DATA HIDING VIA LINE-BASED CUBISM-LIKE IMAGE

IDEA OF PROPOSED DATA HIDING TECHNIQUE

In the proposed Cubism-like image creation process described above, one major step is to recolor the pixels in each image region with the average color of all the pixels in the region, resulting in an image visually looking like the source image. We take advantage of this step as well as a weakness of the human visual system in differentiating small color changes to design the data hiding technique in this study. To be more specific, the proposed data hiding technique embeds message data into a cover cubism-like image by changing each pixel's color value in the cover image for the minimum amount of ±1 in each color channel. As a result, people cannot tell the visual difference between the cover image and the stego image. This effect, in addition to that of attracting people by the artistic content of the Cubism-like image, gives the proposed data hiding technique a camouflage effect which arouses no suspicion from hackers. Furthermore, a reversible region recoloring scheme, which keeps the average color of each region unchanged, is designed as a substitute of the original recoloring process. This reversibility guarantees that we can extract the data embedded in the stego-image to restore the original content of the cover image losslessly. It is also noted that changing pixels' colors slightly while keeping average region colors unchanged, as proposed, creates integrally a mosaic effect in the regions, which makes the stego-image look nearly identical to the cover image and thus enhances the camouflage effect of the proposed technique. The proposed data hiding technique as described above is designed according to theorems derived from the rounding-off property in integer-valued color computation. The details are described next.

PRINCIPLE OF LOSSLESS DATA EMBEDDING

In the proposed region recoloring process, when embedding a bit into a pixel with color , if is 0, then we decrement by an integer value 1, and if is 1, then we increment by 1. After hiding message bits into the pixels' colors in a region by color shifting in this way, the region's average color will also be changed. It is found in this study that the property of rounding-off in integer computation may be utilized to modify this region recoloring process to keep the average region color unchanged, resulting in a reversible region recoloring process.

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The proposed data hiding process, which is based on the creation process of the line-based Cubism-like image and the lossless data embedding principle described previously, is composed of two stages—data string randomization and embedding capacity computation; and data embedding. In the first stage, at first we transform the data string to be hidden into a digit sequence of 0's and 1's and append an ending pattern (with at least one digit other than 0 and 1) to the end of the sequence to keep its length a multiple of three. By the ending pattern, we can determine where the embedded data string ends in a sequence of extracted digits in the later data extraction process. Next, we try to obtain the information of two parameters of each region, namely, its area and average color, by performing Algorithm 1. Then, we use a secret key to randomize the order of the regions in the input image, and take the resulting sequence as the order for data hiding. For each region, in order to keep the average color of the region unchanged, we limit the embedded amount of message data bits in each region by the constraint. In the second stage, we embed the input data sequence by shifting the pixels' colors for the amounts of according to the above-mentioned data hiding order. After the data sequence is exhausted, there might exist regions into which no data is embedded. We deal further with these intact regions to keep the coloring style of all regions consistent. For this, we create a random binary string of 0's and 1's with the bit numbers roughly constrained by (2), and use the same data embedding process to embed it into the intact regions. At the end, a stego-image is generated with the input data string embedded imperceptibly.

STEPS FOR EMBEDDING A DATA INTO CUBISM-LIKE IMAGE

1.Data String randomization
1.1 Randomize and segment data string.
1.2 Transform the data string into binary string and randomize the order of the bits to generate a new string using secret key.
1.3 Each bit as a digit and append an ending pattern with at least one or more than three identical digits to form a new digit sequence with its length being a multiple of three.
1.4 Divide it into sequence of 3-digit sequence.
2. Generate an art image and compute the areas and average colors of the region in the image.
3. Calculating the maximum embedding capacity of each region
4. Data Embedding.
4.1 Randomize the order of the pixels to generate an ordered pixel sequence using function with the secret key.
4.2 Embed the 3-digit sequence with digits of sequence into n unprocessed pixel with color values taken sequentially from pixel sequence.
5. Repeat steps 3 & 4 if the sequence is not exhausted.
6. The remaining regions are embedded with false data so that attackers has a confusion that which region has the original data.
7. The final Image is taken as the stego-image.

DATA EXTRACTION PROCESS

The proposed data extraction process, is basically a reverse version of the proposed data hiding process and consists of two stages—embedded data extraction and data derandomization. In the first stage, we recover the region recoloring sequence in the stego-image and obtain the area and the average color of each region in the stego-image. Based on the average color of each region, we retrieve the message data embedded in the stego-image by comparing it with the pixels' colors in the region. In the second stage, the retrieved data are derandomized to get the original message data using the secret key.

STEPS FOR EXTRACTING THE HIDDEN DATA

1.Extracting the region with related parameters.
2. Retrieving the region recoloring sequence.
3. Create a message data sequence with empty content.
4. Extracting the embedded content
4.1 Randomize the order of the pixels to retrieve the pixel coloring sequence using function with secret key.
4.2 Take sequentially an unprocessed pixel with color in sequence.
4.3 Extract three embedded data digit from the difference values between the color of pixel and average color of the region.
5. Data Derandomization; reorder the digits using function with secret key and then transform he binary to character to get a data string.

KEY EXCHANGE

Through out the whole process a single key is used. This key should be very important. So Diffee Hellman Key Exchange algorithm can be used for transferring the key from sender to receiver.

SECURITY MEASUREMENT

Under the usual assumption that the algorithms are known to the public, a hacker could extract the embedded data from a stego-image by the proposed data extraction process. Against this, we adopt four measures to enhance the security of the proposed technique using a secret key: (1) randomization of the data string to be embedded; (2) randomization of the processing order of the regions; (3) randomization of the processing order of the pixels in each region; and (4) embedding camouflage strings in intact regions to mislead a hacker to guess data in them erroneously. With these measures, the risk for the embedded data to be stolen by a hacker is greatly reduced.

CONCLUSION

A new method of combining art image generation

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and data hiding to enhance the camouflage effect for various information hiding applications is proposed. At first, a new type of computer art, called line-based Cubism-like image, and a technique to create it automatically from a source image have been proposed. The method finds line segments in the source image by the Canny edge detection technique and the Hough transform, combines nearby line segments, extends the remaining lines to the image boundaries, and recolor the created regions by their average colors, to create an abstract type of the original source image as the desired art image. Then, by utilizing the characteristics of the Cubism-like image creation process, a data hiding technique has been proposed. Based on the minimum color shiftings of the values of ±1 , the technique embeds message data into the pixels of the regions of the generated art image while keeping the average region colors unchanged. The data embedding process is proved to be lossless by theorems so that the cover image can be recovered perfectly after the embedded message data are extracted. The proposed method has several merits. First, it generates Cubism-like images as stego-images to distract the hacker's attention to the message data embedded in them. Also, by using the minimum color shiftings of to ±1embed data bits, the resulting pixels' color differences between the generated Cubism-like image and the stego-image are so small that a hacker will take no notice of the existence of the hidden data. Consequently, the proposed data hiding technique is very suitable for use in covert communication or secret keeping. Furthermore, four measures of randomization of the input message data and the processing order of them with a secret key and several random-number generating functions have been adopted in the proposed method. This enhances greatly the security of the proposed method.

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