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Generation of Photo-Mosaic Images through Block Matching and Color Adjustment

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***Abstract*—**Mosaic refers to a technique that makes image by gathering lots of small materials in various colors. This paper presents an automatic algorithm that makes the photo-mosaic image using photos. The algorithm is composed of 4 steps: partition and feature extraction, block matching, redundancy removal and color adjustment. The input image is partitioned in the small block to extract feature. Each block is matched to find similar photo in database by comparing similarity with Euclidean difference between blocks. The intensity of the block is adjusted to enhance the similarity of image by replacing the value of light and darkness with that of relevant block. Further, the quality of image is improved by minimizing the redundancy of tiles in the adjacent blocks. Experimental results support that the proposed algorithm is excellent in quantitative analysis and qualitative analysis.

***Keywords*—**Photo-mosaic, Euclidean distance, Block matching, Intensity adjustment.

I. Introduction

MOSAIC makes figure or image by attaching small pieces or tiles in various colors on the basic draft [1]. When mosaic images are viewed in short distance, we can see small pieces and when they are viewed in long distance, we can see one large form made by the pieces. Mosaic has been mostly done by artists. In these days, such mosaic work is fixed as one of unrealistic rendering techniques by researchers of computer graphics. The images made by this technique enhance the interest and artistic property of image. In the past, many materials should be collected for long time for this mosaic. However, this problem is considerably solved by low-priced digital device that is launched recently in wide variety. Because of the appearance of software that can be easily used by general users, they are much interested in mosaic management. Thus, unrealistic rendering technique recently becomes the target of embodiment for many graphic designers rather than technology of some researchers and mosaic in diverse types are introduced.

Photo-mosaic refers to make one large photo by collecting many small photos. Due to the recent development of digital imaging technology, these photo-mosaic technologies are actively used in magazine, poster, installation, music video and TV advertisement [2]. Since the mosaic images are mostly made by specialized graphic designer manually, it is difficult for general users to make photo-mosaic images. Even specialized graphic designer takes long time to make mosaic image, because work is done manually.

This paper proposes an automatic photo-mosaic algorithm through block matching and intensity adjustment. First, the input image is split into block unit to extract feature. Then, each block is compared with photos in photo database to finds the similar photo with the block. The value of lightness and darkness of photo matched last is replaced by that of the relevant block to enhance similarity of the image. Also, the quality of mosaic image is improved by applying technique that minimizes redundancy of the same photo between adjacent blocks. Also, the performance of the proposed algorithm is compared with Andrea software. The paper is composed as follows. Related works are summarized in Section II and the proposed algorithm to make photo-mosaic images is proposed in Section III. Experimental result is presented in Section IV and Section V concludes.

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II. Related Works

Since photo-mosaic was introduced by Silvers [3], automatic photo-mosaic software is only studied by some developers and speed or quality is not yet improved satisfactorily. Also, photo-mosaic images currently commercialized are mostly made by manual work.

Klein et al. proposed a video mosaic algorithm [4]. For a moving image, the matching between blocks is performed by comparing similarity by using the feature of average color values in YIQ domain and 3-dimensional wavelet disassembly. Also, overlay is performed to combine images. Although the overlay makes the overall influence to be more natural than simple color matching, but the quality of each tile image is rapidly lowered and image contents are perverted. Although there is some difference depending on performance of computer, it takes 3 hours and 47 minutes to produce moving image in 10 seconds. Thus, this method cannot show detailed image of photo in the photo-mosaic image, but simply deliver the mosaic effect.

Fig. 1 Sample photo-mosaic images by fast photomosaic [5]

Fast photo mosaic algorithm improved speed compared to the existing photo mosaic algorithm [5]. Color matching was applied after splitting input image by 3×3 for RGB domain.

Especially, it was tried to improve performance by Antipole clustering. Although no specific algorithm was presented and no experiment was compared with the existing studies, it took 5.98 seconds to make photo-mosaic in the size of 320×240 and 32.49 seconds to make a mosaic image in the size of 1024×768 in the consideration of difference in the performance of computer. Further, it is difficult to discern image of tile used in the produced result in Fig. 1 and the quality of photo-mosaic is unsatisfactory due to no color adjustment of tile.

III. Proposed Photo-mosaic Method

This section presents our automatic photo-mosaic algorithm through block matching and intensity adjustment. The proposed algorithm is composed of 4 steps: image partition and feature extraction, block matching, redundancy removal and color adjustment.

First, (Step 1) the input image is split into the previously set block size to extract feature. (Step 2) The similarity of split blocks are compared with the photo of database to perform block matching that finds the similar photo in the database. (Step 3) The process to minimize the redundancy of photo between adjacent blocks and to reduce using repetitious photo is done. (Step 4) Finally, the value of light and darkness of matched photo is replaced by that of the relevant block to adjust the brightness value that heightens image similarity so as to make photo-mosaic image in. Each step will be explained specifically in the next Section.

A. (Step 1) Partition and Feature Extraction

The first process to make photo-mosaic image is to split the input image into small blocks so as to calculate the feature of each block. The calculated feature is utilized in process of block matching. As shown in Fig. 2, the input image is split into blocks of pre-set size and each block is divided into 16 areas (4×4) to calculate the average RGB value of each area so as to use it as the feature of each block. Thus, 48 feature values can be extracted for each block.

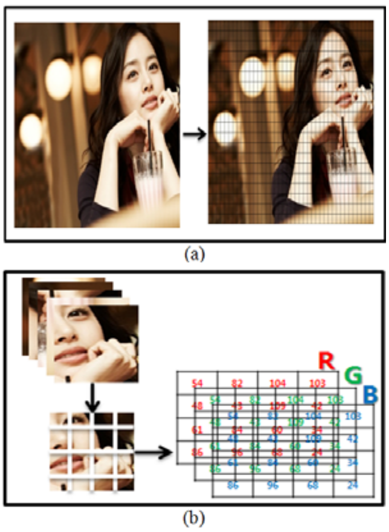

Fig. 2 (a) Image split into 64×64 pixel block and (b) extracting average value by dividing block into 16 segments

This process to calculate such feature values is same to that to extract the feature values of photo included in the photo database (the block size was set to 64×64 pixel unit in this experiment). For the photo database, only the whole photo is split into 4×4 area to calculate the average RGB value of each area. The number of feature values is more than that of those by Blasi and Petralia method [5].

B. (Step 2) Block Matching

To compare the similarity of block, the difference between feature values of block is calculated based on modified Euclidean distance. Euclidean distance is widely used to calculate the distance between two points as follows:

$$d(p,q) = \sqrt{(p_1 - q_2)^2 + \cdots + (p_n - q_n)^2} = \sqrt{\sum_{i=1}^{n} (p_i - q_i)^2}$$

To measure the similarity of RGB pixel values, the above equation is modified as below.

$$D = \sqrt{(r_1 - r_2)^2 + (g_1 - g_2)^2 + (b_1 - b_2)^2}$$

D represents a Euclidean difference of RGB values between compared pixels. When the *D* has a low value, that compared pixels have a high similarity. However, considering all pixels in images requires high computational complexity.

To improve the computational efficiency, the proposed algorithm extracts 48 feature values from the block and the similarity can be calculated from the following formula, where k means feature value.

$$\text{Difference} = \sum_{k=1}^{48} (\text{OriginalB}(k) - \text{ComparedB}(k))^2$$

Therefore, from the block of an input image, the 48 feature values is extracted and used to calculate the similarity with that from the photo database as shown in Fig. 3. Calculating speed was improved by deforming Euclid Distance that calculates the distance between 2 dots on the basis of measuring similarity between blocks to eliminate/utilize root calculation.

Fig. 3 The similarity comparison between the block of the input image and the photo database

The image combined by block matching pertains to image having the lowest similarity value among those in the following formula, where *SB(k)* means k^{th} feature value of each split block and $DB_i(k)$ means the k^{th} feature value of photo i in photo database.

$$\text{MatchBlock} = \min\left\{\sum_{k=1}^{48}(\text{SB}(k) - \text{DB}_i(k))^2\right\}$$

C. (Step 3) Redundancy Removal of Photo

If the same photo is inserted into adjacent block, photo-mosaic quality is lowered. Thus, minimizing photo redundancy is a process to prevent the insertion of the same photo in the adjacent block.

If photo pertaining to peripheral block is already used to minimize photo redundancy, the photo with other best value is searched for use. Further, the repetitious use is limited by measuring the times to use the photo in the photo database.

For blocks, the block matching process starts from the left top area to the right bottom area. Thus, when the block matching is carried on for random block, only blocks on the left top area are matched. To test redundancy for the proposed algorithm, peripheral block included in the range of 45~180 degree was searched on the basis of block for matching as in Fig. 4. The depth for search was set to 3. Given that block for matching is $B_{i,j}$ and the peripheral block is $B_{k,l}$, *max*(|i-k|, |j-l|) value, namely, the maximum value of distance difference means the searching depth. If the searching depth is low, it is quite likely that the similar photo is to appear and if the searching depth is deep, computational time is lengthened, as many blocks must be compared in the block matching process.

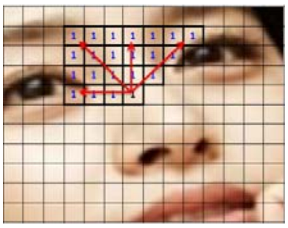

Fig. 4 Peripheral block comparison to minimize photo redundancy when depth is 3 (blue)

The result made by applying block matching and technique minimizing redundancy is indicated in Fig. 5. The result before eliminating redundancy is shown in left and result minimizing redundancy is shown in right, which implies the improved quality of qualitative mosaic image.

Fig. 5 Result before and after photo redundancy removal

D. (Step 4) Color Adjustment

Although the photo set to the optimum value in photo database through block matching is applied to make a photo-mosaic image, the color sense is quite different from the original image as shown in Fig. 6.

In the brightness value adjusting process, the quality is improved by adjusting photo intensity in photo database so that it can be similar to the brightness value of the original image block. To this end, the photo and original image block is changed to HSI domain and the brightness value data of photo is replaced by the brightness value data of original image block to be converted into RGB domain image so that the brightness value of set tile can be adjusted. As shown in Fig. 6, the quality is improved at the boundary part compared to that before adjustment. Further, natural image can be made through this process without overlapping original image.

Fig. 6 Image before and after replacing light and darkness value of tile

IV. Experimental Result

To rate the performance of the proposed photo mosaic algorithm, it was comparatively analyzed with the result of Andrea mosaic software [6]. Algorithm was tested under same condition in the environment of Intel(R) Core i5 650 processor, nVidia GeForce 310 and memory 3GB DDR3 computer.

In Table I, experimental results are summarized for 10 test images. An original image is shown in Fig. 7. Since the size of photo-mosaic images generated from the proposed algorithm and Andrea mosaic software is different, intuitive comparison is difficult. However, it could be confirmed that although the memory use of the proposed algorithm is high, the usage of CPU is low and the computation time is low.

TABLE I
Result of Analyzing Average Algorithm Performance for 10 Images

	Our algorithm	Andrea software
Image size (pixel)	3072 x 2304	4281 x 3425
Number of photos (pcs)	1728	2068
Block size (pixel)	64 x 64	98 x 73
Memory capacity	400mb	100mb
Max. number of redundant photos	5 or 10 pcs	5 or 10 pcs
Number of photos in use	266 pcs	266 pcs
CPU Usage	30%	80 ~ 100%
Computation time	4.3~5.2 sec.	7~8 sec.

In Figs. 8 and 9, the photo-mosaic result from the proposed algorithm and Andrea mosaic is depicted where the number of redundant photo is limited to 10.

In the case of Andrea mosaic, when the number of redundant images is limited to 5, the photo-mosaic result included several empty spaces because all block of an input image are not filled with photos. When redundant photos are limited to 10, the result of normal photo-mosaic is made as shown in Fig. 9. However, it still fails to meet the satisfactory quality of photo-mosaic images. In the other hands, the proposed algorithm can make high quality photo-mosaic image similar to the color sense of original by adjusting brightness value as shown in Fig. 8.

Fig. 7 Original image

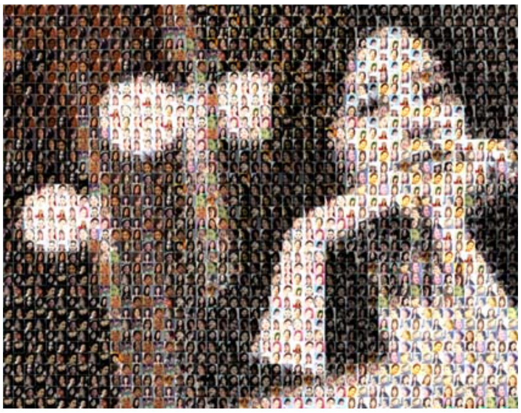

Fig. 8 Photo-mosaic result from the proposed algorithm

Fig. 9 Photo-mosaic result from Andrea software

The quality of photo-mosaic image cannot be easily measured quantitatively. While PSNR (*dB*) can be used to quantitatively analyze the difference between original and mosaic images, the accuracy is far from the real-quality of actual photo-mosaic. Thus, we performed a quantitative analysis of the mosaic results from the proposed algorithm and Andrea mosaic software by asking 57 users.

In the aspect of quality, the quality is analyzed to select excellent one among two photo-mosaic results. The analyzed result is arranged in Table II and the preference of the proposed photo-mosaic algorithm is 77% which is much higher than Andrea mosaic.

TABLE II
RATING QUALITY OF PHOTO-MOSAIC IMAGE BY 57 USERS

	Our algorithm	Andrea software
Preference	44 persons (77%)	13 persons (23%)

V. CONCLUSIONS

Because of the development of digital imaging technology, the photo mosaic technology that makes image by using photo is utilized. Since most photo-mosaic technologies are manually performed by specialized designer, considerable time is spent and they cannot be easily done by public due to technical difficulty.

This paper proposed an automatic algorithm that makes photo-mosaic image through block matching and image adjustment. The performance of the proposed algorithm was compared quantitatively and qualitatively with Andrea mosaic program. The result support that the proposed algorithm can achieve the high quality photo-mosaic image. Further work is to minimizing the computational cost by optimizing the algorithm.

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