Removal of Moving Objects and Inconsistencies in Color Tone for an Omnidirectional Image Database

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Abstract. This paper proposes a method for removing image inconsistencies which occur by an existence of moving objects or a change of illumination condition when an omnidirectional image database is generated. The database is used for archiving an outdoor scene in wide areas or generating novel view images with an image-based rendering approach. In related work, it is difficult to remove moving objects in an outdoor environment where illumination condition drastically changes, and to remove inconsistencies of color tone of images which included moving objects. The proposed method iterates the two processes which are the estimation of candidate region of moving objects and the achievement of color consistency to split regions. The color consistency is achieved by estimating linear color transformation parameters which change a histogram of an input image to that of the standard image.

1 Introduction

In a panoramic image view system such as Google Street View, a user can see images from a street using omnidirectional images. Some studies [1, 2] which use omnidirectional images can also generate a novel view with an image-based rendering (IBR) approach in an outdoor environment. These studies use an image database which consists of many images captured with an omnidirectional camera. When the image database is generated from many images which are captured at different position and time, these images have inconsistencies which occur by an existence of moving objects or a change of illumination condition.

As a method for removing moving objects in images, a technique of compensation using images which is captured at different time is used usually. A color tone differs only in the complemented regions when a simple compensation approach is applied using an image whose color tone is different from the original image. Shadow in an image is also treated as a region of moving object. A technique of removing shadows corresponding to change of illumination [3] is proposed by estimating a light source condition. However, it is difficult to detect an object whose color is similar to the color of background.

On the other hand, as one of the methods for removing an inconsistency in color tone of images, a technique which handles an image whose color tone is different locally [4] is proposed. In this technique, color consistency in images is achieved by splitting the input image to small regions. However, the method is difficult to be applied when moving objects exist in an image, because a static environment is assumed in this method. The work [5] which removes moving objects after correcting a color tone detects moving objects with a slight change of illumination condition. This study cannot be applied to the case that an illumination condition changes drastically such as an outdoor scene.

If the conventional approaches are applied to the images captured in an outdoor environment, there are many problems such as the existence of moving objects and the change of illumination conditions. Furthermore, in order to capture in an outdoor environment efficiently, when omnidirectional camera is used, moving objects are easy to be captured and change of illumination condition is large. This paper proposes a method for removing inconsistencies among omnidirectional images captured at different positions and times. This research assumes an outdoor environment is a target of an omnidirectional image database. We use omnidirectional images which are captured several times along similar paths with a car-mounted omnidirectional camera. We assume that these images add position and posture information, and are captured densely. To remove inconsistencies of omnidirectional images, the proposed method iterates the two processes which are removal of moving objects and achievement of color consistency of images. The iteration of two processes can narrow down a region of moving objects and omnidirectional images with consistency of color tone are generated.

2 Removal of moving object and inconsistencies in color tone for omnidirectional image database

2.1 Outline of the proposed method

This section describes a method for generating an omnidirectional image database with consistency of images. Fig. 1 shows the flow diagram of the proposed method. The proposed method consists of three principal processes.

First, omnidirectional image sequences with camera positions and postures are acquired in an outdoor environment. As the pre-processing, we remove the regions which cannot be corrected by linear color transformation in phase (A). In the iteration processing (phase (B)-(D)), two processes which are estimation of linear color transformation parameters in phase (B) and estimation of candidate region of moving object in phase (C) are iterated by splitting regions in phase (D). Finally, as the post-processing, candidate regions of moving objects are compensated in phase (E). Details of each phase are given below.

2.2 Pre-processing: removal of exceptive regions for iteration process

When inconsistencies in color tone are removed, we assume that color tone of images can be changed by linear color transformation except in a region where

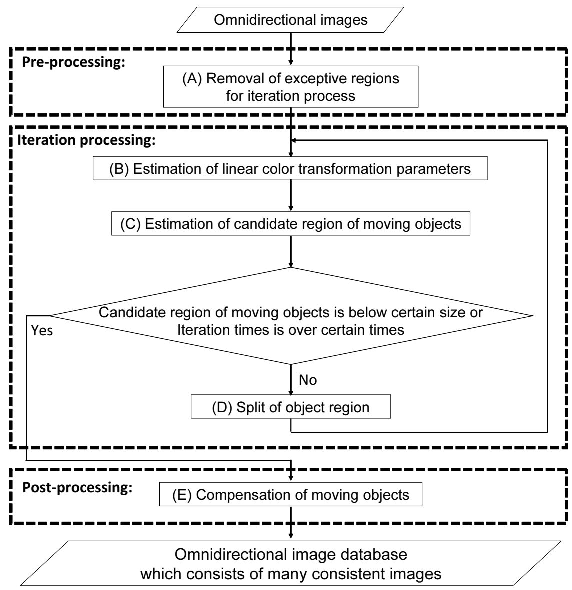


Fig. 1. Flow diagram of proposed method

moving object is observed. It cannot assume that color of the sky region is transformed to the color of standard image by linear transformation since intensity of the pixel in the region is often saturated or background image cannot be defined due to cloud. In this study, the sky region in the omnidirectional images is detected and removed in advance. These can be realized by using the previous methods [6, 7].

2.3 Iteration processing: estimation of candidate region of moving object and linear color transformation parameters

This section explains the method to realize a consistency of omnidirectional images with the following iteration processes.

Estimation of linear color transformation parameters for color correction A color tone of input omnidirectional images is corrected with a standard image. The standard image which is suitable for an IBR approach is selected manually. Since input images have a few disparities when they are captured with a moving vehicle, the color transformation parameters cannot be estimated for every pixel. In this research, to reduce the influence of the disparities, histograms of the standard image and the input image are used for estimating color transformation parameters.

We assume that it is possible to correct the color tone of an image with a linear color transformation if a different appearance depends on changes in illuminate conditions. An equation which changes intensity in image is shown in Eq.(1).

$$I'(x, y) = p_a I(x, y) + p_b, \quad (1)$$

where linear color transformation parameters are p_a, p_b, $I(x, y)$ is intensity at (x, y) of input image and $I'(x, y)$ is intensity at (x, y) after correcting color. The color transformation parameters are estimated in such way that the similarity value of histogram between the input image and the standard image becomes the highest. In this method, Bhattacharyya coefficient(2) is used as a similarity of histogramsγ. Bhattacharyya coefficient has the advantage of robustness for outlier by using inner product.

$$\gamma = \sum_i \sqrt{h_{A(i)} h_{B(i)}}, \quad (2)$$

where $h_{A(i)}$ shows a frequency of intensity i in image A, and $h_{B(i)}$ shows that in image B. Histograms are generated in each spectrum.

Color correction based on robust estimation Color of moving objects can not be corrected with the linear color transformation. Then, after removing moving objects, to correct a color tone is desired. The region of the moving objects is difficult to extract from one image or some images which have a different color tone. In this research, we try to estimate color transformation parameters by eliminating the moving objects with a LMeds [8] approach as a robust estimation. In order to estimate color transformation parameters based on the LMedS method, the candidate region of moving objects needs to be less than half of an object region. If regions of moving objects are less than half of an object region, the color transformation parameters can be estimated by iterating a random sampling.

The color transformation parameters in every region which is extracted by a random sampling are estimated with an evaluation function based on a histogram's similarity. If there are no moving objects in the region, the same color transformation parameters should be estimated in each region. Then, color transformation parameters which are estimated in each region are applied to other regions. If there are no moving objects in the applied regions, the similarity value of histograms between the color corrected image and the standard image becomes higher. On the contrary, if there is the region which includes moving objects, the similarity value of histograms becomes lower. If an area where moving objects do not exist is more than half of the region, similarity value of histograms is calculated without the effect of moving objects by extracting a median of similarity values. Finally, color transformation parameters p_a, p_b when a similarity value is the highest in all regions are applied for the input image which is pre-processed in section 2.2. As a result, consistency of color tone is possible by removing the moving object. However, if an occupied rate of moving objects is more than half of the region, iteration process which is explained below is needed.

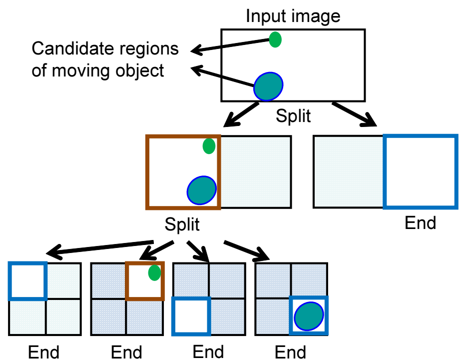


Fig. 2. Split of object region

Estimation of candidate region of moving object Regions of moving objects are estimated by calculating a difference of intensity between the corrected image and the standard image. Since the omnidirectional images are captured with a motion omnidirectional camera, a few disparities are existed between input images. Therefore, when the difference of an intensity value is calculated, a template matching approach is performed for every region and a candidate region of moving objects is estimated in consideration of the disparities between omnidirectional images. Here, an image which is masked to the region of moving objects is generated and is used for the region split in the following paragraph.

Split of object region In each region for processing, when an occupied rate of moving objects is more than a fixed rate, the object region is split and color transformation parameters are estimated. This is based on an idea that areas with different transformation parameters are existing in one region for processing. Appearance of re-splitting the input image is shown in Fig.2. The color transformation parameters of a major object in the region can be estimated with this approach.

By iterating these processes, color consistency of images except in a region where the moving object is observed is achieved. Estimation of color transformation parameters which are robust to the influence of disparity is possible by maintaining a certain size of the split region.

2.4 Post-processing: compensation of moving objects

Even if the calculated transformation parameters are applied for the input image, the moving objects which exist in the image can not be removed only by iterating the color consistency processing. In our work, the candidate object regions are compensated using other corrected omnidirectional images which are captured at near positions. Here, there is an assumption that a background of the moving object exists in the corrected input images. When the regions of moving objects are compensated, to consider the disparities between input images, the corresponded region with the area of moving objects are searched from the input images.

3 Experiments

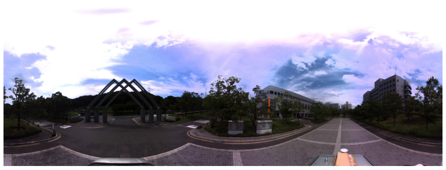
3.1 Experimental environment

In the experiment, we used omnidirectional images which are captured with a car-mounted omnidirectional camera as input images and removed inconsistencies among them. We used an omnidirectional multi-camera system (Ladybug2, Point Grey Research) for capturing in an outdoor environment. 5 omnidirectional images which were captured at near positions were used for input images. Since each image is captured at different time, color tones differ respectively. In this research, we assume that camera positions and postures can be acquired with some sensors [1] or by a vision-based approach [9]. Fig.3 shows examples of input images. There are some moving objects in each image and it turns out that color tones are different due to a change of illumination condition. Each image has disparities due to a difference of captured positions.

3.2 Experimental results

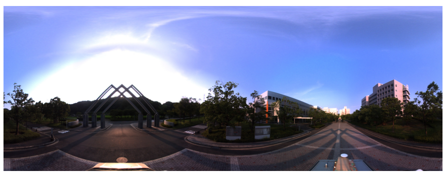
The standard image which has no moving object and are suitable for an input of an IBR approach are selected as shown in Fig.3(a). The regions which are not necessary for color consistency, like sky region and equipment of capturing system were removed in advance from the input images.

Fig.4 shows the intermediate results of color consistency using LMeds method to image A. The result of color consistency without splitting regions is shown in Fig.4(a). Here, since a set of transformation parameters were estimated to whole image and were applied to the input image, it turns out that some regions has a different color tone between the input image and the standard image. The difference of intensity value between the color corrected image and the standard image was computed as shown in Fig.4(b), In this figure, regions which have large difference of intensity are masked red. This result shows that it is difficult to correct color tone only with a set of transformation parameters. Input image should be split into small regions and color transformation parameters should be estimated in each region. Next, the region which is estimated to be a moving object is split and the color transformation parameters based on robust estimation are estimated recursively. The result of color consistency with iteration processes is shown in Fig.4(c). The comparison of the results as shown in Fig.4(d) shows that iteration processes are effective for removing inconsistencies among omnidirectional images. Fig.5 shows the results of compensation of moving objects using the corrected images. In each image, it turn out that moving objects are removed by the compensation.

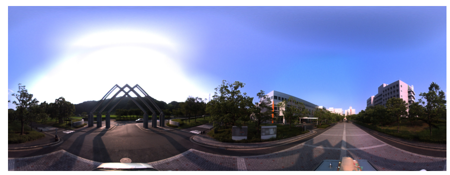


(a) standard color image

(b) image A

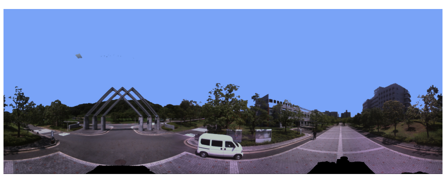


(c) image B

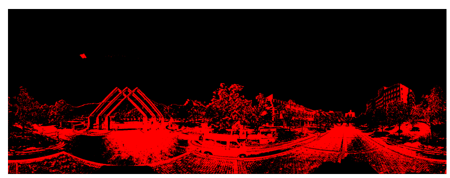


(d) image C

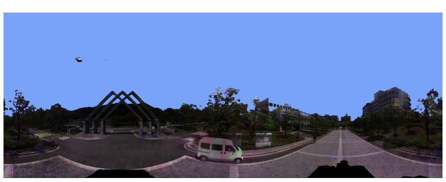
Fig. 3. Examples of input images which are captured at different times in nearby positions.



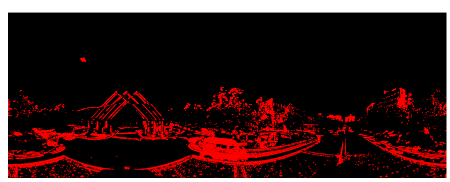
(a) result of color consistency without splitting regions



(b) estimation of candidate of moving object (Red areas are estimated regions of moving object.)



(c) result of color consistency with iteration processes



(d) estimation of candidate of moving object after iteration processes (Red areas are estimated regions of moving object.)

Fig. 4. Result of color consistency with iteration processes to image A in Fig.3

To verify the validity of the proposed method, we conducted a quantitative evaluation. Similarity of histogram between the standard image and the color corrected image was used for evaluation. Bhattacharyya coefficient was used as a similarity of histograms. Table.1 shows the similarity value of histogram with the standard image. It turned out that the similarity of the histogram with the standard image was improved for every result.

Finally, as an application, novel view images were generated with the IBR approach[1] using the generated omnidirectional image database. Fig.6 shows the novel view images which are generated by using omnidirectional images. The result as shown in Fig.6(a) has inconsistencies which occur by a change of illumination condition. Fig.6(b) shows good result by using the proposed omnidirectional image database.

4 Conclusion

In this paper, we have proposed the method for removing inconsistencies which occur by an existence of moving objects or a change of illumination condition when an omnidirectional image database is generated. Our approach has realized consistency of images with the iteration processes which are the estimation of candidate region of moving objects and the achievement of color consistency to split regions. Consistency of color tone is realized by estimating linear color transformation parameters which change histogram of the input image to that of the standard image. In experiments, we have confirmed that the proposed method can remove inconsistencies among omnidirectional images for an image database. As a future work, we have to make a large-scale omnidirectional image database.

Acknowledgement
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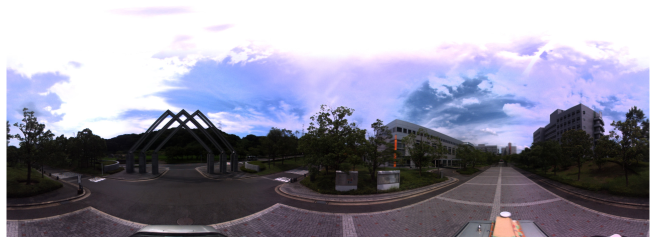
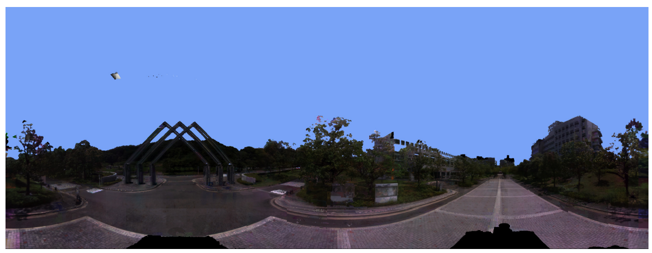
Table 1. Similarity value of histogram with color standard image (1 is the highest similarity value.)

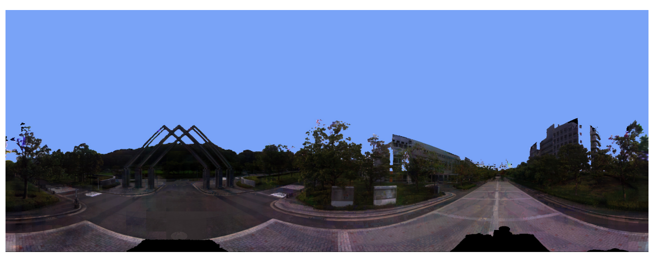
		R	G	B
Image A	input image	0.8429	0.8996	0.8877
	proposed method	0.9945	0.9925	0.9916
Image B	input image	0.9585	0.9703	0.9669
	proposed method	0.9943	0.9921	0.9918
Image C	input image	0.9717	0.9740	0.9697
	proposed method	0.9955	0.9935	0.9934
Image D	input image	0.9036	0.9265	0.9251
	proposed method	0.9944	0.9909	0.9920
Image E	input image	0.9203	0.9346	0.9306
	proposed method	0.9913	0.9817	0.9856



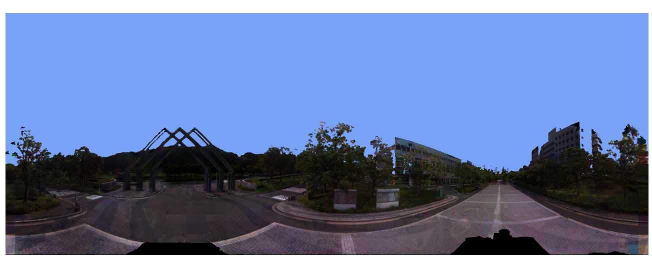
(a) standard color image



(b) image A

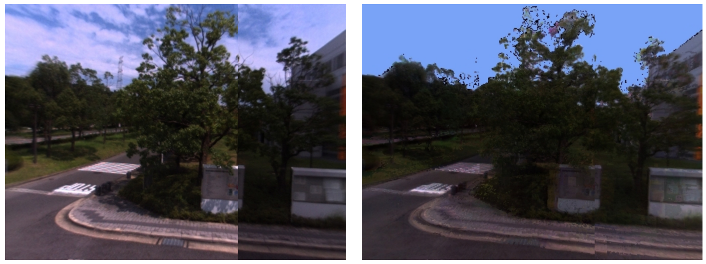


(c) image B



(d) image C

Fig. 5. Result for removing moving object and inconsistencies of color tone to input images in Fig.3



(a) Generation result from original omnidirectional images.

(b) Generation result from proposed omnidirectional image database.

Fig. 6. Novel view images which are generated from omnidirectional images with the IBR approach.

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