A Simple and Efficient Approach for Creating Cylindrical Panorama

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ABSTRACT

The methods of image registration and fusion are very important basis of cylindrical panorama creating. There are many relevant algorithms been developed, but many of them usually have limitations on their qualities and efficiency. In this paper, an automatic approach for creating cylindrical panorama is introduced. Compared with many commonly used algorithms[7, 10], this algorithm is simple and effective. In our method, we adopted an FFT-based phase-correlation algorithm to register images, and we also employed a multi-resolution pyramid algorithm to perform image fusion. By preprocessing the input images using such methods as histogram equalization, we further increased the accuracy and robustness of image registration. Our experiments show that the method is simple, efficient and effective.

Keywords: panorama, IBR (image-based rendering), image registration, environment mapping

1. INTRODUCTION

In recent years, there has been increasingly more research interest in IBR (image-based rendering) techniques, which has a potential broader application in computer graphics, computer vision and many other fields. The foundation of IBR is the plenoptic function theory that is brought forward by Adelson and Bergen[1]. Based on this theory, McMillan and Bishop stated a specific definition being used in IBR. A prototype system is also implemented in their work[4]. Following this work, various techniques have been developed. Among these works, cylindrical panorama[2], concentric mosaics[15] and lumigraph [13, 14] are some notable ones. More detailed evolutions of these techniques can be found in Shum[3] and Kang's[5] recent works.

Panoramic mosaic is a fairly practical technique in IBR[2]. In this technique, a panorama is created by stitching a series of images taken from different view angles at a fixed viewpoint. After stitching, it can be re-projected onto certain environment models such as cylindrical or sphere ones to reproduce the recorded environment in a photo-realistic quality.

There have been a number of approaches been developed for creating the panorama. Various environment models (sphere, cylinder, and cube) have also emerged for these approaches. Because the cylindrical model is more convenient to store, and requires less images for creating the panorama than others, we in this paper only discuss the approaches for cylindrical panorama creation. Among those newly introduced approaches, some approaches [6, 4, 7, 12] tend to recover 3D affine relations between images with a matrix representation to register images precisely. These methods are a kind of optimal process. They can represent 3D relations of images accurately, and is suitable for various environment models. But for cylindrical panoramas, these methods are too complex because the relationships between images with the same view point and closer view angles can be simplified as a translation operation [11, 8]. In some other methods [9, 10, 17], the registration algorithm tends to find out the optimal match of the image features. They are not robust for the images with obvious lighting differences. Moreover, in order to create cylindrical panorama precisely, the parallax introduced by projective transformation from plane to cylinder, which is not concerned by some methods[10], must be taken into account.

In order to avoid the limitations of the works stated above, this paper presents a novel approach for creating cylindrical panorama. In our work, an FFT-based phase-correlation algorithm for image registration is adopted, and a multi-resolution pyramid algorithm is also employed to blend the images. By preprocessing the input images using such methods as histogram equalization, accuracy and robustness of image registration for cylindrical panorama is further increased. A cylindrical mapping and focal length estimation are also presented in this paper to create an accurate view parallax. The experiment result indicates that the approach is ideal regarding the quality, effectiveness and efficiency.

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The remaining of our paper is organized as follows. Section 2 discusses image registration and fusion methods. Section 3 describes our method of constructing cylindrical panoramas, and some effective preprocessing techniques are also given in this section. Section 4 and 5 present the experiment result and conclusion respectively.

2. RELATED WORKS

The two major issues in image mosaicing are image registration and image fusion. In this section, we discuss and compare various relevant methods, and choose some preferable methods to be used in panorama creation.

2.1 Image registration

Image registration means to identify the relationships between images (translation, rotation, scaling). Due to their importance in many fields, various methods of image registration have been developed. Brown[18] has summarized and compared some state-of-the-art methods. Since the relations between images with the same view point and closer view angles can be simplified as a translation relationship, we focus on the translation relationship between images.

According to Brown's summarization[18], the techniques on image registration can be divided into two classes: methods in space domain and ones in frequency domain. The former ones tend to find out the optimal match of the image features. Since the features detected for image matching is not equally effective for all the images, these kinds of algorithms are not always robust.

To avoid above drawbacks, registration methods in frequency domain have emerged. Among these methods, the FFT-based phase-correlation algorithm is implemented widely[19]. This method is more robust because it is independent of image features. Therefore, it is particularly useful for registering images obtained with different illumination conditions. Detail analyses of the algorithm have been given by Manduchi and Mian[22]. The algorithm itself is described below.

As shown in Fig.1, given a translation relationship between (1) and (2) (the overlapped part of the two images is shown as a shaded area), the target of the algorithm is to obtain the translation vector between the images. In our algorithm, a Fourier transform is defined as:

$$\xi\{f(x,y)\} = \hbar(\omega_x, \omega_y) \tag{1}$$

where ξ denotes Fourier transform， f denotes original function and $\hbar$ denotes resulted function.

Then, according to transnational feature of Fourier transform (translation in space domain is equal to phase change in frequency domain), the following equation is obtained:

$$\xi\{f(x+\Delta x, y+\Delta y)\} = \hbar(\omega_x, \omega_y)e^{j(w_x\Delta x + w_y\Delta y)} \tag{2}$$

So, the relationships between the two images in Fig.1 can be represented as:

$$\hbar 1(w_x, w_y)e^{j(w_x\Delta x + w_y\Delta y)} = \hbar 2(w_x, w_y) \tag{3}$$

i.e.:

$$e^{j(w_x\Delta x + w_y\Delta y)} = \frac{\hbar 2(w_x, w_y)}{\hbar 1(w_x, w_y)} \tag{4}$$

By performing inverse Fourier transform on equation(4) ,following equation is obtained：

$$Coor(x,y) = \xi^{-1}\{e^{j(w_x\Delta x + w_y\Delta y)}\} = \delta(x-\Delta x, y-\Delta y) \tag{5}$$

where $\hbar 1, \hbar 2$ denote the Fourier Transforms of the two images, $\Delta x, \Delta y$ denote shift coordinates.

Function $\delta(x-\Delta x, y-\Delta y)$ can be visualized and a typical situation is shown in Fig.2. In Fig.2, the function can be found clearly as a perfect impulse and the coordinate of the peak is the marching point, so the translation vector can be obtained from the coordinate.

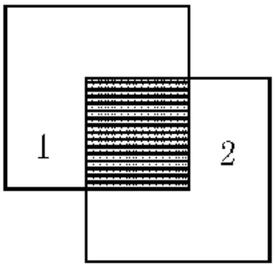


Figure 1. Image translation

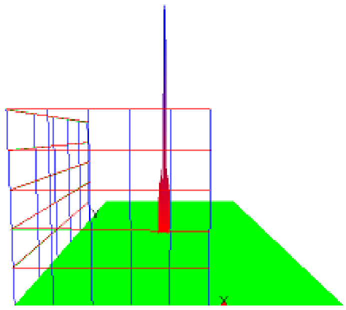


Figure 2. A typical phase correlation surface

The algorithm stated above is a phase-correlation algorithm in its basic form, and some development can be made. Reddy and Heng[20] extend this algorithm so that it is able to deal with rotation and scaling between images. Their algorithm also forms a uniformed FFT-based technique for translation, rotation, and scale-invariant image registration. Recently, Averbuch and Keller[22] have optimized the phase-correlation algorithm to have sub-pixel accuracy. The advantage of their algorithm is characterized in that the calculating amount of FFT can be reduced by processing the images on a low-resolution level. Therefore, it is obviously suitable for the use in our panorama creating.

2.2 Image fusion

Another major step of our panorama creation is image fusion, which stitches the registered input images together to form a single panorama image. In order to stitch adjacent images seamlessly, image fusion on the registered images is necessary. Among many fusion methods currently available, the easiest one is linear blending over the overlapped part. This algorithm is not effective enough because it often produces a “double exposed” look in the blending zone and so more research efforts have been made over it[23]. Some other methods introduced wavelet techniques into image blending which increased computing complexity as a side effect.

In contrast, the multi-resolution pyramid-blending algorithm makes better tradeoff between computing complexity and blend effectiveness. In this approach, the images are decomposed into band-pass pyramid levels (In the following, we call the images resulted in these pyramid band levels as *component images*), and then they are blended at each band-pass pyramid level with different blending zone. The process smoothes the illumination discontinuities, and at the same time preserves the image sharpness. Since the component images in each spatial frequency band are dealt with separately, so better quality is obtained. Liu Guixi and Yang Wanhai[25] compared this method with others, and the conclusion also shows this method’s effectiveness.

3. CONSTRUCTION OF CYLINDRICAL PANORAMA

During the creation of the panorama, many factors may have negative effects on accuracy and quality of image registration and blending. Therefore, preprocessing may be helpful for eliminating these negative effects. This section discusses the preprocess methods which we adopt, and summarizes our method for the construction of cylindrical panorama.

Firstly, we converted input color images into gray ones. Because each pixel has three values (Red, Green and Blue) in a color image, we can make use of the phase-correlation method on gray value by this convert. This preprocess reduced the calculation amount of FFT of three-color plane into one single gray plan and will decrease the computing time.

Secondly, although the phase correlation algorithm had been designed against the sensitiveness of the illumination change between images, but in practice registration errors will appear when the large illumination discontinuity is found between input images. In order to increase the accuracy of image registration, we introduced certain preprocesses on the image brightness. In our method, histogram equalization is performed on all input images, which makes brightness and color of all input images looks the same on the whole. In this way, the registration accuracy is increased and Fig.3 shows the effects of this method. In Fig.3, (a) and (b) are two overlapped images taken by a digital camera which have obvious differences in brightness; (c) is a stitched image by the phase-correlation algorithm which is not preprocessed by histogram equalization; (d) is the result image using histogram equalization. Compared with (c), (d) is preferable regarding the registration accuracy.

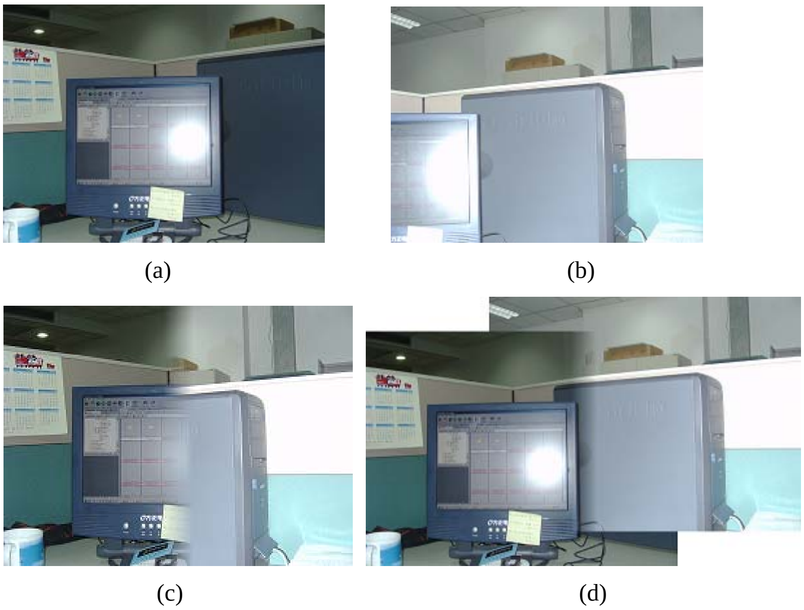


Figure 3. The result of image registration.

In addition to the histogram equalization, we also adopted a Low-Pass filter to increase the accuracy of registration. This target of this process is to eliminate the high-frequency noises that have negative effect on phase correlation algorithm. Although Low Pass filter will also eliminate some high frequency information of an image, they are not significant in the algorithm.

According to the development on phase-correlation algorithm by[22], we may perform phase-correlation algorithm on low-resolution level images, and then convert the translation coordinates into the position on original images. Note that the two images at the beginning and the end of the image sequences must be registered and stitched in order to create 360-degree seamless panorama.

The panorama created by the directly stitching of input images does not exactly follow the cylindrical environment model. As an example, Peleg's method[11] performs in this way, the method only stitches strips in the middle of each image, and its effectiveness decreases when less input images are used. To maintain the effectiveness of the method even when less input images are used, another preprocess is necessarily introduced. This preprocess is the projective transformation that maps a planar image into a cylindrical surface.

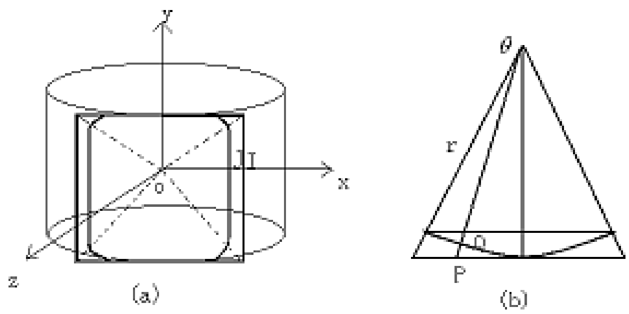


Figure 4. Cylindrical projection transformation

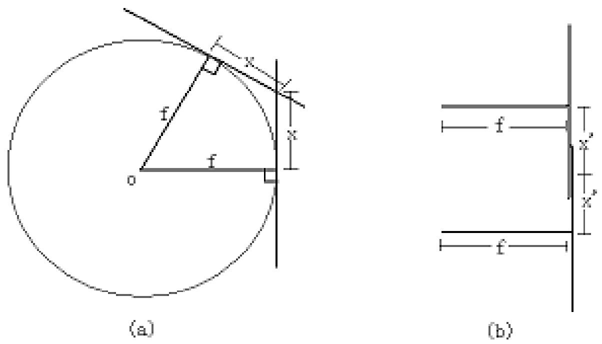


Figure 5. Relationships of adjacent images.

The projective method is shown as Fig.4 that presents the projective relationships. In Fig.4, image I and J denote two corresponding images on different surfaces. Based on their geometry relationship, the relation between the coordinates P (x, y) on image I and Q (x', y') on image J can be described as:

$$x' = r \cdot (\theta / 2) + r \cdot (\tan^{-1}((x - w/2)/r)) \tag{6}$$

$$y' = h/2 + (y - h/2) \cdot r / k \tag{7}$$

where $k = (w/2 - x)/\sin(\theta/2 - x'/r)$, h denotes the height of planar images, w denotes the width, r denotes the focal length.

There are two variables in above equations, that is θ and r. We may only compute the value of r, since θ can be derived from r. The algorithm of computing r is described as follows.

Fig.5 shows two adjacent images at the same point in 2D format. In Figure 5, (a) illustrates the real geometry relation, and (b) is an approximate situation. Due to similarity between them, we can assume that the x' in (b) equals to x in (a). Considering a 360-degree panorama, we can obtain below equation:

$$360 - 2\sum_n \tan^{-1}(x_n / f) = 0 \tag{8}$$

where f denotes the focal length, x_n denotes the distance from the image center to the intersection of adjacent images.

This equation can be easily solved with Newton's method[21], and the initial value for iterations may be defined as:

$$f = \frac{\sum_n x_n}{2\pi} \tag{9}$$

With the above algorithm, a planar image can be projected into a cylindrical surface. The result is shown in Fig.6, in which (b) is obtained by projecting (a) into a cylindrical surface.


(a)


(b)

Figure 6. The result of the projective transformation.(b) is obtained by projecting (a) into a cylindrical surface.

Based on the description given above, the method for creating cylindrical panorama is given as follows:

1. Converting all input images into gray ones.
2. Performing histogram equalization on all input images
3. Performing FFT on all input images
4. Low-Pass filtering all images in frequency domain
5. Performing phase-correlation algorithm on each two adjacent images, and find out translation coordinates
6. Estimating the focal length and project all input images into cylindrical surfaces
7. Stitching all the projected images with multi-resolution pyramid method

4. RESULTS

Through the methods described above, we can fast construct panoramic mosaics from a set of images. Fig.7 shows two 360-degree panoramas that are created with our method. Note that all the images are taken with a hand-held digital camera. Fig.8 shows the scan results at the center of cylinder form different view angles.

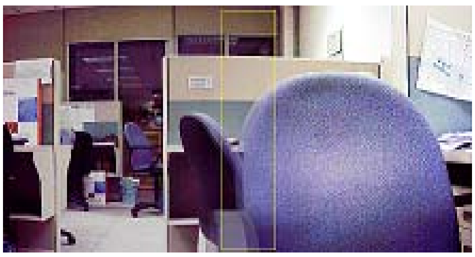
In the process of image stitching, we blend the overlapped zone of adjacent images with the multi-resolution pyramid method. The result is shown in Fig.9, where the yellow rectangular frames denote blending zones. (a) is the result using the linear blending, and (b) is obtained with the multi-resolution pyramid method.

(a)

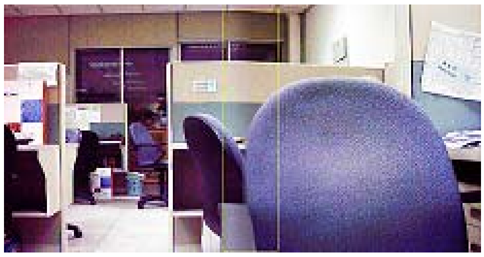
(b)

Figure 7. The two panorama mosaics created by our method.

Figure 8. The three local scenes that are obtained from different view angle when Fig.7 (a) is navigated



(a)



(b)

Figure 9. The results of two image fusion methods.

5. CONCLUSIONS

In this paper, a simple and effective approach for creating cylindrical panorama is introduced. We adopt an FFT-based phase-correlation algorithm to register images, and a multi-resolution pyramid algorithm to perform image fusion. We have also presented the methods for estimating the focal length of the input images and cylindrical mapping. Moreover, by preprocessing the input images using such methods as histogram equalization**,** we further increased accuracy and robustness of image registration. Although many current methods recover the 3D affine relationships between the adjacent images and adapt to many environment models[6, 7], our method is more simple and efficient for cylindrical panorama.

If environment information such as scene depth, movement and illumination is considered, panoramic mosaics can simulate real scenes better[8, 15]. Based on the works in this paper, we will explore how to describe them in panorama.

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