An Image Stitcher and Its Application in Panoramic Movie Making

Chia-Yen Chen and Reinhard Klette*

Abstract

This paper describes the design and implementation of an image stitcher which can be used to join colour images. The images are joined in two steps. The first step involves registering two adjacent images using a minimum absolute difference method. The second step adjusts the contrast of the joined images using a linear interpolation of the intensity difference between the two images.

The images joined by the stitcher can be used in many applications, such as panoramic viewing, architectural walk through and other teaching or researching purposes.

---

*   The University of Auckland, Tamaki Campus, Computing and Information
    Technology Research, Computer Vision Unit, Auckland, New Zealand

An Image Stitcher and Its Application in Panoramic Movie Making

Chia-Yen Chen and Reinhard Klette
Computing and Information Technology Research – CITR
Department of Computer Science, Tamaki Campus
The University of Auckland, Auckland
New Zealand
E-mail: {cche019, rklette}@cs.auckland.ac.nz

Abstract

This paper describes the design and implementation of an image stitcher which can be used to join colour images. The images are joined in two steps. The first step involves registering two adjacent images using a minimum absolute difference method. The second step adjusts the contrast of the joined images using a linear interpolation of the intensity difference between the two images.

The images joined by the stitcher can be used in many applications, such as panoramic viewing, architectural walk through and other teaching or researching purposes.

Keywords: *image stitching, panoramic image*

1. Introduction

In recent years, interactive movies have become more and more popular, for educational as well as commercial purposes. One of the most common kind of interactive movie is the panoramic movie, which allows the user to change the view directions, as well as zoom in and out of the scene.

A panoramic movie can be generated by joining a series of overlapping images taken by a camera set on a tripod. The images are then joined by the stitcher software to form a panoramic image. Common problems in joining a series of images include the misalignment of images and the sharp edges formed when the colour intensities between the images are not uniform.

The features required in an image stitcher may include the accuracy in joining the image, the ability to adjust colours, the simplicity of usage, and flexibility in its application.

There are image stitchers available from the internet. However, these stitchers do not offer the range of functions described above in one package. Commercially available stitchers do not describe the methods used in stitching and are also restricted in their functions and applications. Knowing about these methods is essential for performance evaluation [5].

A new image stitcher has been designed and implemented to join a set of given images together to form a panoramic image. The stitcher is especially implemented to adjust the colours of the images so that the transition from one image to the next will be very smooth. The resultant panoramic image can then made into an interactive panoramic movie using public domain software to demonstrate the possible applications of the stitcher.

The methods used in implementing the new image stitcher are described and discussed in this paper so that a detailed understanding of the image stitcher can be reached.

2. Joining of images

The process of forming larger images with sets of smaller, overlapping images has been used from as early as the 1950's [1]. The process, known as mosaicking, was used then to manually join aerial images together. Nowadays, with the available software and hardware, image mosaicking can be performed at a fraction of the time as before and with much better results.

The following describes a method especially designed to perform image mosaicking on a given set of colour images.

2.1 Image registration

In order to form a larger image with a set of overlapping images, we need to find out exactly where the overlap occurs so that the images can be joined together. This process, or image registration, can be performed in a number of ways. The process used in our image stitcher adopts a minimum absolute difference approach to register the images.

Due to the nature of panoramic images, we have assumed that the translation between two adjacent images will mostly be in the horizontal direction to improve the efficiency of the algorithm. However, a small vertical shift is still allowed to account for the errors in taking the photos.

It is also assumed that the photos have been taken in a clockwise order. So that part of the right hand side of the kth image should be identical to part of the left hand side of the $(k+1)$th image.

Let I_k be the kth image in the sequence of images and let $W_k(x,y)$ be the window defined on I_k, centered in position (x,y) of the image. The method used to find the corresponding window in I_{k+1} is to find a position in I_{k+1} such that the absolute difference $D(u,v)$,

$$D(u,v) = \sum_{(i,j)} |W_k(x+i,y+j) - W_{k+1}(u+i,v+j)|$$

(1)

between $W_k(x,y)$ and $W_{k+1}(u,v)$ is minimised. The absolute value is used instead of the squared error for efficiency. The registration algorithm further assumes that at the position of the least

absolute difference, $W_k(x,y)$ corresponds to $W_{k+1}(u,v)$ so that I_k can be joined to I_{k+1} with a horizontal translation of u-x and a vertical translation of v-y. Several initial positions (x,y) are used to detect the optimal global translation.

The relative size of the windows with respect to the image size is an important factor in this method. Since if the window is too big, the calculations of the differences will be slow and cumbersome. But if the window is too small, there is not enough information contained in the window to provide a reliable position for overlapping.

Other factors to be taken into consideration are the positions of selected windows, W_k. If W_k is positioned in a homogeneous area, the determination of the minimum absolute difference may not lead to an optimal solution. Therefore, W_k is preferably chosen in a region where the image will less likely to be homogeneous. W_k also has to be positioned within an area where I_k and I_{k+1} overlap. Otherwise, the calculation for the minimum absolute difference might not give an accurate result. The a-priori knowledge about the camera rotation angle can also be used to constrain the starting positions of W_k.

Keeping the above mentioned factors in mind, the first window W_k has been positioned towards the right hand side of the image and centered vertically. This position has been chosen with the above assumption that the images are taken in a clockwise order, hence the right hand side of I_k will overlap with the left hand side of I_{k+1}. The first W_k has been centered vertically because it can be a general assumption that there is some inhomogenity in the center of the image.

For example, the size of W_k has been chosen to be approximately 128 by 80 for a set of twenty four images with resolution of 256 by 160, taken by a 35mm camera. A window of this size is big enough to provide a reliable matching position without unnecessary calculation and within the overlapping region of the images.

W_{k+1} is shifted across I_{k+1} within a defined region to find a position (u,v) in I_{k+1} where D is minimised. The region is defined to be where the overlap is likely to occur and is bounded by a horizontal threshold, H, and a vertical threshold, V. So, the value of u and v can be determined by minimising

$$D(u,v) = \min_{x-H \leq i \leq x+H,\, y-V \leq j \leq y+V} \{D(i,j)\}. \quad (2)$$

The image registration algorithm is originally applied to the luminance channel of the input images to reduce processing time since the luminance channel contains sufficient information for the matching of features. However, when there is a significant amount of difference in intensity, a false overlapping position might result.

Edge detection is performed on the original images in order to correct the problem caused by the intensity difference. We selected a simple operator (Sobel operators) after looking at a diversity of edge operators [6], since it is sufficient to provide an edge image suitable for our purpose.

The Sobel operators are applied to the luminance channel of the image to produce an edge image. The image registration process is then performed on the binary edge images as before. This step eliminates the false matches resulted from the significant difference in image intensities.

Figure 1a: Input image

.

Figure 1b: Input image

Figure 1a and 1b are a pair of adjacent input images. It can be seen that there is a considerably large overlapping regions and a significant amount of intensity difference.

Figure 2 shows the result of applying the image registration algorithm on Fig. 1a and 1b.

The minimum absolute difference used as a matching criterion in this process is both simple to implement and faster to calculate in the long run. The usual approach of minimum difference square has produced about the same results. However, the later approach requires more processing time. Therefore, the minimum absolute difference approach has been adopted.

As mentioned before, it has been assumed that the minimum absolute difference between $W_k(x,y)$ and $W_{k+1}(u,v)$ implies that the points (x,y) and (u,v) corresponds to each other. However, that might not be true for some cases because of various reasons. One reason might be that there is a significant amount of intensity difference between the input images, caused by the sun light, the exposure of the camera, or parallex errors. However, this method is both simple and quick to implement and works well as long as the binary edge maps of the image, which contains sufficient features to be registered, can be obtained.

2.2   Colour adjustment

The process of simply concatenating the images is not enough to produce a convincing panoramic image. Since the differences in intensity between some adjacent images are too great to be ignored. Therefore, a way to reduce the significant difference in intensity is needed to remove the distinct edge at the seam and to smooth the transition from one image to the next.

In [7], a method for joining a pair of gray-level satellite images has been described. However, our stitcher has to join up a given set of more than two coloured images, e.g. twenty-four colour images taken by a normal 35mm camera. There is a considerable amount of intensity variance within the set of images. More care needs to be taken when adjusting the intensity levels so that the overall intensity of the resultant panoramic image will look uniform.

In the implementation of this section, a few methods have been tried, on images in both the YIQ and the RGB models. Even though the results produced by some methods are not very satisfactory, they can be used as references for those who might wish to pursue further researches in associated areas.

The method which produced the best result finds the differences between two columns which are immediately next to the seam and linearly interpolates the difference over a neighbourhood in I_k and I_{k+1} using the RGB model. Details of this method are described in the following.

From 2.1, the overlapping regions in the images have been obtained. This information can be used to define each image's contribution to the final image. Let l_k and r_k be the left most and right most columns of the region contributed to the final image by image I_k.

Let

$$E_k(s) = I_k(s, r_k) - I_{k+1}(s, l_{k+1}) \qquad (3)$$

be the intensity differences between the two columns r_k and l_{k+1}.

The purpose of colour adjustment is to make the edge produced by the intensity difference, $E_k(s)$, less noticeable to the viewer.

The method proposed here is to linearly spread the effect of $E_k(s)$ over a specified neighbourhood, so that the change in intensity will be gradual and less detectable. Let N be the size of the neighbourhood, so that $E_k(s)$ will be spread over N pixels on the left and right hand sides of the seam.

Since $E_k(s)$ will be linearly distributed over an interval of $2N$ columns, the effect of $E_k(s)$ on each column will be

$$e_k(s) = \frac{1}{2N} E_k(s) \qquad (4)$$

more than the previous column.

The difference in the colour intensity is spread over I_k and I_{k+1} in the following way

$$I_k(s, r_k - h) = I_k(s, r_k - h) - (N - h)e_k(s)$$
$$I_{k+1}(s, l_{k+1} + h) = I_{k+1}(s, l_{k+1} + h) + (N - h)e_k(s)$$
$$(5)$$

This method is able to produce a smooth transition between the images as shown in figure 3. The final image produced by joining a set of twenty-four given images is shown in figure 4.

3. Summary

The design and implementation of a new image stitcher have been described and discussed in this paper. The implementation of the stitcher can be divided into two phases; image registration and colour adjustment.

In the image registration step, minimum absolute difference has been used as a criterion for the matching of overlapping positions. The Sobel operators have been used to produce the binary edge images on which the registration algorithm is performed.

In the colour adjustment step, a linear interpolation of the intensity difference has been used to reduce the intensity difference between two adjacent image. This method can smooth out the edge in adjacent images which have, on average, a factor of about 1.4 in the intensity differences.

The image stitcher implemented using the above described methods can be used to join a series of images. It is currently designed to produce panoramic images which can be used as inputs for single node panoramic movies. The stitcher is fully automatic and requires only the minimal amount of information about the images.

Further studies in this area can include more sophisticated algorithms for even more accurate and efficient image registration, as well as better functions for colour adjustment. One method current being investigated is the use of a binary search approach in image registration. Other possible functions of the stitcher can include a mapping function, which maps the resultant panoramic images onto certain geometric models to produce more realistic images.

6. References

[1] American society of photogrammetry, Manual of photogrammetry, 2nd ed. Wisconsin: George Banta publishing co., 1952.

[2] K. R. Castleman, Digital image processing, New Jersey: Prentice Hall, 1996.

[3] S. E. Chen, "QuickTime VR - An image based approach to virtual environment navigation", Proc. SIGGRAPH, pp. 29-38, 1995.

[4] S. E. Chen, "View interpolation for image synthesis", Proc. SIGGRAPH, pp.279-285, 1993.

[5] P. Courtney, Neil Thacker and Adrian Clark, "Algorithmic modelling for performance evaluation", Workshop on performance Characteristics of vision algorithms, April 1996.

[6]   [6]   R. Klette and P. Zamperoni, "Handbook of image processing operators", Chichester: John Wiley & Sons,   1996.

[7] D. Milgram, "Computer methods for creating photomosaics", IEEE Trans. Comput., vol. C-24, pp. 1113-1119,   Nov. 1975.

[8] D. Milgram, "Adaptive techniques for photomosaicking", IEEE Trans. Comput., vol. C-26, pp. 1175-1180, Nov. 1977.

[9] S. Peleg and J. Herman, "Panoramic mosaics by manifold projection", Proc. CVPR, Jun. 1997.

[10]   S. Salmond, "Image stitcher", http://m3r.tcs.auckland.ac.nz/~ssal002.

Figure 2:   Result of image registration

Figure 3: Result with colour adjustment

Figure 4: Result of joining twenty four images