The Gentle Spherical Panorama Image Construction for the Web Navigation System*

Min-Jen Tsai, Chi-Long Kao and Jung Liu

Institute of Information Management, National Chiao Tung University, R.O.C.

ABSTRACT

Among different multimedia format, the panorama images could present the real-life spatial scenery in the Internet which offers better viewing angles than traditional 2D images and videos. This study provides a gentle approach which only takes two images to create the spherical panorama images for the 3D viewing environment as a virtual tour navigation system with low cost (less than $2000 for the whole system). By the help of the 183 degree fisheye lens, the self developed pano head which positions the lens at the center of shooting angle, and the auto-morphing algorithm to transform the fish eye images into the spherical panorama images, the proposed navigation system can easily demonstrate the interior profile, layout of the 3D environment, and the viewing coverage on the screen which offers the detailed information, photos, hot spots for hyperlinks on the web pages. Therefore, the whole spherical panorama images can then be created seamlessly and conveniently for the 3D usage on the Internet which extends the usability for the panorama image based systems.

Index Terms—fisheye, spherical panorama, navigation.

1. INTRODUCTION

In the digital world, almost everything is displayed on the Internet. Since the Internet communication speed and bandwidth increases daily, it enables users to request the multimedia content to obtain the information. Among different multimedia format, the panorama images could present the 3D real-life spatial scenery on the Web which offers better viewing angles than images and videos. Many real estate agents, touring services already offer 2D scene images but few provide 3D information online.

A panorama is made by at least two images or by tens of images. More images will increase the complexity of shooting and stitching, and may cause discontinuity, discordant color levels and inconsistent brightness, which results high production cost for high image resolution. Therefore, this study focuses on how to use two images to create the spherical panorama images, simplify the shooting labor and the assembling methods for panorama image production.

This paper will be organized as follows. The details of the approach will be explained in Section 2. Section 3 will demonstrate the designed web navigation system and conclusion is in Section 4.

2. THE APPROACH

A spherical panorama, covers 360 degree point of views, needs at least two shoots. Using the fisheye lens with more than 180 degree angle, we can capture half of the spherical image. To get another half of the spherical image, we need to rotate the lens 180 degree with the help of the pano head with the fixed position at the rotation center. Fig. 1 shows the relationship between the shooting angle and the fisheye lens image [1, 2].

The two images made with fisheye lens are twisted due to the lens characteristic. Therefore, we need to correct the twists and project them to the coordinate system of spherical panorama before assembling. During the assembling stage, we need to adjust the overlapped area, as shown in Fig. 9 for both images. The detailed procedures are as following.

2.1. INTRODUCTION OF THE SPHERICAL COORDINATE SYSTEM

Although each of the two images covers half of the spherical view, the scene has been twisted to a circle, due to the 183 degree fisheye lens. Therefore, we need to find the relationship between the following two coordinate systems:

1. The spherical coordinate system: the points in the cubic space $P_1(x_1, y_1, z_1)$ as shown in Fig. 2.
2. The fisheye coordinate system: the points projected by the fisheye lens $P_2(s_1, t_1)$ as shown in Fig. 6.

The point O is the origin point of the spherical coordinate system in Fig. 2. $P_1(x_1, y_1, z_1)$ is the referred point shot from the scene through the lens, and P_1' is the projection point of P_1 on the $x-y$ plane. We denote the following polar coordinate axis, (r, θ, ϕ).

1. Radius r : the distance between origin point O to P_1.
2. Longitude angle θ : the angle between the positive x-axis and the vector $\overrightarrow{OP_1'}$, the range is between 0 and 2π $(0 \le \theta < 2\pi)$.

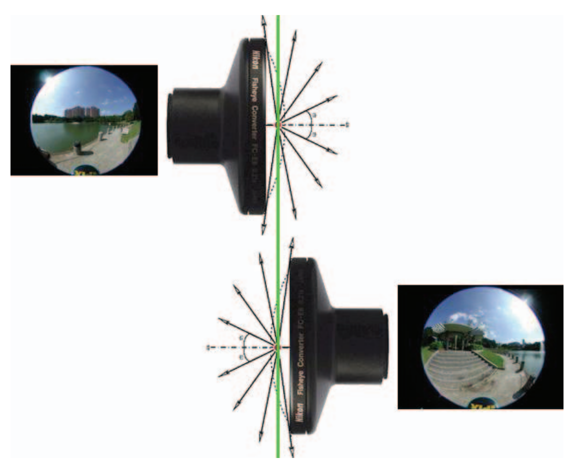

Fig. 1. The relationship of the shooting angle and the fisheye lens image for the spherical panorama

* This work was partially supported by the National Science Council in Taiwan, Republic of China.

3. Latitude angle ϕ : the angle between the positive z-axix and the vector $\overrightarrow{OP_1'}$, the range is between 0 and π ($0 \le \theta \le \pi$).

The relationship of (r,θ,ϕ) in the spherical coordinate system and (x_1, y_1, z_1) in the cardinal coordinate system is shown below:

$$x_1 = r\cos\theta\sin\phi \quad (1)$$

$$y_1 = r\sin\theta\sin\phi \quad (2)$$

$$z_1 = r\cos\phi \quad (3)$$

2.2. THE CORRECTNESS OF THE TWISTED IMAGE FROM THE FISHEYE LENS

In Fig. 3, the relationship of the fisheye lens with the scene location is shown for illustration [3]. The fisheye lens is placed at origin O , the center of the sphere with the direction faced at the positive y-axis. The cardinal coordinates of the point P_1 in the spherical image is (x_1, y_1, z_1) in Fig. 2 and the distance to the center O is the radius r in Fig. 3. The projection point Q at the y-axis is y_1 and angle between the vector $\overrightarrow{OP}$ and positive y-axis is θ_1. θ_1 is called as the view angle of the image point P . We denote θ_1 with the value of (x_1, y_1, z_1) as the viewpoint of P by the right triangle ΔOPQ as below:

$$\cos\theta_1 = \frac{y_1}{r} = \frac{y_1}{\sqrt{x_1^{\,2} + y_1^{\,2} + z_1^{\,2}}} \quad (4)$$

The image twisted to a circular image due to the 183-degree fisheye lens is shown in Fig. 4. Assuming the radius of the 180-degree image is R and the projection point P_2 of P on the plane $x-z$, has the distance to the centre O is r_2. The view angle θ_2 has positive relationship with r_2. Therefore, we can obtain the relationship among the distance r_2 between P_2 and center O , the radius R , and the view angle θ_2 of P_2, the ratio called ρ_1 is shown below:

$$\rho_1 = \frac{r_2}{R} = \frac{\theta_2}{\frac{\pi}{2}} = \frac{2\theta_2}{\pi} \quad (5)$$

The angle between vector $\overrightarrow{OP_2}$ and the positive z-axis is called θ_2 , and θ_2 is the direction angle of the point P_2 as shown in Fig. 5. The relationship of P_2 and the point P_1 (x_1, y_1, z_1) will be calculated as following.

The projection point of $P_1(x_1, y_1, z_1)$ on plane $x-z$ is P_2 as shown in Fig. 5. The projection point of P_2 on positive z-axis is Q, and we get $\overline{P_2Q} = x_1$ and $\overline{OQ} = z_1$. In addition, the angle between vector $\overrightarrow{OP_2}$ and positive z-axis is θ_2 with the range from 0 to 2π . We can obtain the relationship between the direction point P_2 , θ_2 and the point $P_1(x_1, y_1, z_1)$, by the right triangle ΔOP_2Q as following:

$$\sin\theta_2 = \frac{x_1}{\sqrt{x_1^{\,2} + z_1^{\,2}}}, \cos\theta_2 = \frac{z_1}{\sqrt{x_1^{\,2} + z_1^{\,2}}} \quad (6)$$

The point P_3 at the fisheye lens image is shown in Fig. 6. The coordinates at the x-y plane is (x_3, y_3) and we can obtain the associated coordinates at the fisheye projection plane $(r_1\cos\theta_3, r_1\sin\theta_3)$, where θ_3 is the angle between point P_3 and positive x-axis, and $r_1 = R \times \rho_1$, $\theta_3 = 90° + \theta_2$. If the ratio of x_3 and radius R is s_1 , the ratio of y_3 and radius R is t_1 , the formulas can be simplified by equation (5):

$$s_1 = \frac{x_3}{R} = \frac{r_1\cos\theta_3}{R} = \frac{R\cdot\rho_1\cdot\cos(90°+\theta_2)}{R} = \frac{2\theta_1}{\pi}\cdot(-\sin\theta_2) \quad (7)$$

$$t_1 = \frac{y_3}{R} = \frac{r_1\sin\theta_3}{R} = \frac{R\cdot\rho_1\cdot\sin(90°+\theta_2)}{R} = \frac{2\theta_1}{\pi}\cdot\cos\theta_2 \quad (8)$$

There are several methods to turn the spherical images into the spherical panoramas. In this study, we use the cylindrical equidistant projection as shown Fig. 7 [4]. The characteristic of this approach is that the vertical coordinates of the projection has the positive relationship with the angle of elevation or depression which makes the distance corresponding to the view angles. If the width of the panorama is W, height is H, $W = 2H$, and the coordinates of point P_3 is (w_1, h_1) . By comparing the relationship between Fig. 4 and Fig. 6, we can obtain w_1 which is the ratio of x coordinate of point P_3 and the width of $\frac{W}{4}$, h_1 which is the ratio of y coordinate of point P_3 and the height $\frac{H}{2}$. The relationship can be formulated below:

$$w_1 = \frac{x_3}{\frac{W}{4}} = \frac{4x_3}{W} = \frac{4x_3}{2H} = \frac{2x_3}{H} = \frac{\theta}{\frac{\pi}{2}} = \frac{2\theta}{\pi} \quad (9)$$

$$h_1 = \frac{y_3}{\frac{H}{2}} = \frac{2y_3}{H} = \frac{\phi_1}{\frac{\pi}{2}} = \frac{2\phi_1}{\pi} \quad (10)$$

Using the relationship discussed above, we transform the coordinate system (s_1, t_2) of the twisted image into the spherical polar coordinate system (θ,ϕ) , by letting the camera faces to the

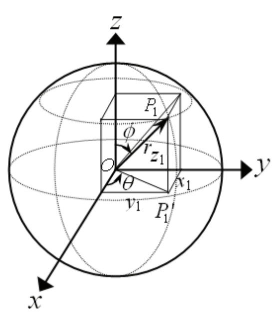

Fig. 2. The spherical coordinate system

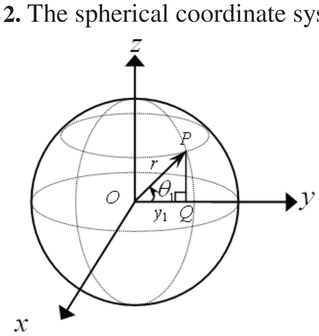

Fig. 3. The relationship of the fisheye lens with the scene location

positive x-axis direction. In addition, we also transform the coordinate system (w_1, h_1) of the spherical image into the spherical polar coordinate system (θ, ϕ), by aligning the left side of the panorama to the x-axis

After these arrangements, we could divide the twisted image into various horizontal and vertical divisions, and the whole image could be dividing into four quadrants. Only the first quadrant on the upper left portion of the image is selected for demonstration since the twisted situation is the same in other quadrants. By simplifying the trigonometric functions of the whole processes, the production of the spherical panoramas could be speeded up. From equation (7) - (10), the following functions can be obtained:

$$\theta = \frac{\pi}{2} \times w_1 \qquad (11)$$

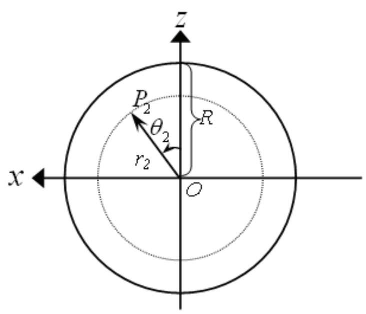

Fig. 4. The fisheye lens projection

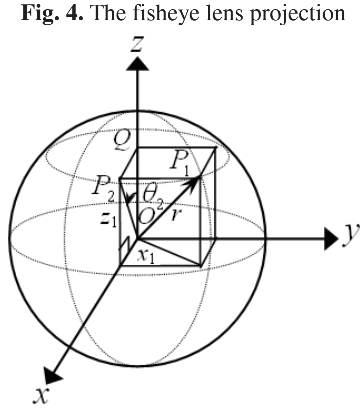

Fig. 5. The relationship of the fisheye lens projection with the scene location

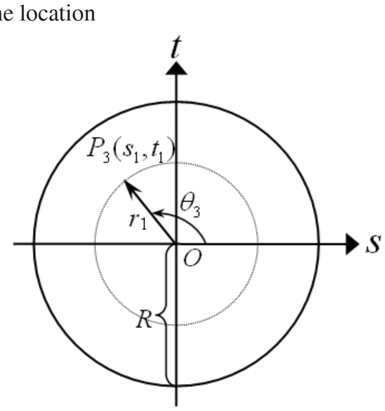

Fig. 6. The fisheye lens projection figure

$$\phi = \frac{\pi}{2} \times (1 - h_1) \qquad (12)$$

We could get a new transformation function T as below by switching these two coordinate systems, (s_1, t_1) and (w_1, h_1) :

$$T : (s_1, t_1) \rightarrow (w_1, h_1) \qquad (13)$$

3. EXPERIMENTS AND DISCUSSION

To demonstrate the effectiveness of the transformation, we transformed the first quadrant of a fisheye image into the spherical panorama as shown in Fig. 8. We can observe that the whole image is a little bit bigger than a quarter of the circle image in Fig. 8(a). The reason is that the visible angle of lens is 183 degree instead of 180 degree and part of the image is twisted, such as the pillar.

After the T transformation process, the pillar becomes straight as shown in Fig. 8(b). There are eight quadrants for two images, and the transformation processes are quite similar as mentioned above. The only difference is they basically have the mirror relationship. Finally, we can assemble the eight-quadrant images to get the spherical panorama as shown in Fig. 9. The self developed software can use the following function icons to output the results and their functions are explained as following:

【Load】 - The first step is to load two of a series of the fisheye images for assembling.

【Config】 - The second step is to input the information of the center position and radius length.

【Correct】 - The third step is to fine tune the center position and radius length.

【Preview】 - The fourth step is to preview the low-resolution

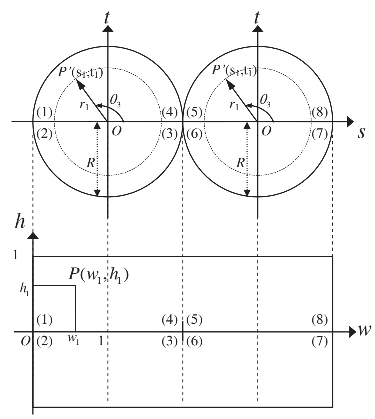

Fig. 7. Equal-space projection of the cylinder

(a) (b)

Fig. 8. The view adjustment from the scene images of fisheye lens (a) to (b)

panorama.

【Output】- The fifth step is to export the high-resolution panorama and the process of a 1600x1200 pixel image costs around 24 seconds by using a notebook with Intel Pentium 3 1G CPU and 256M RAM.

The navigation system provides an operation interface, which can shows detailed profile, layout of the whole environment, and the shooting position on the screen. Fig. 10 shows the self developed pano head and 183 degree fisheye lens for creating the spherical panorama images easily and the total cost for the whole system is less than $2000. Fig. 11 is the campus map with the hot spots which can be linked for browsing. A linked scene image from Fig. 11 is shown in Fig. 12 which can be adopted in the web for navigation system for real estate industry because it provides a convenient way for broker employees to create the virtual tour web pages by applying the existing templates with the tools mentioned in Fig. 9 with low cost. Some real cases have been applied in commercial use and interested readers can refer [5] for comparison. For hotel business, this system is also available to provide detailed online information for tourists, for example, the facilities of the hotels and the room setting. In addition, rich links are available on the same page for information interchange.

4. CONCLUSION

In this study, we have developed the transformation relationship between the fisheye image and spherical panoramas. In addition, we have used 183 degree fisheye lens, the pano head which takes the lens at the center of rotation with the self-developed software, which can transform the fisheye image into the spherical panorama images efficiently. The proposed system can illustrate the interior profile, layout of the 3D object, and the shooting position on the screen. It can import detailed information, photos, hot spots for hyperlinks at the web pages. The whole spherical panorama images can then be created seamlessly and conveniently for the 3D usage on the Internet which extends the usability for the panorama image based systems.

REFERENCES

[1] http://www.ipix.com/. Immersive Photography Homepage.

[2] http://mathworld.wolfram.com/SphericalCoordinates.html. Mathworld Wolfram Spherical Coordinates Homepage.

[3] http://www.panotools.info/mediawiki/index.php?title=Fisheye_Projection. Fisheye Projection Homepage.

[4] http://mathworld.wolfram.com/CylindricalEquidistantProjection.html

[5] http://www.pacific.com.tw/

Fig. 9. The interface of the self-developed software

Fig. 10. The self developed pano head and 183 degree fisheye lens for creating the spherical panorama images

Fig. 11. The campus map with hot spot links

Fig. 12. A linked view from Fig. 11