K-030

A Photo Browser Utilizing 3D Space for Archaeological Field Work

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Abstract

In this paper the authors introduce a new photo browser utilizing virtual 3D space with which users not only see each photo but also have an overview of the scene where the photos are taken. In this photo browser with a special camera, positions and orientations of photos are determined by sun position, the height of the position where the camera is placed and information of a mark point. The simplicity of the constraints and the ability to get an overview of the scene make this photo browser ideal for archaeological field work, which is often carried out in severe conditions.

1. Introduction

The idea of this research arose when the authors carried out the Egypt Al Zayyan Temple 3D Measurement Project [1] in a desert environment. Photo shooting is a suitable operation for investigation in bad conditions, because of simple, strong and durable facilities. But with the conventional photo browser, it is difficult for viewers to get an overview of the scene where the photos are taken.

To solve this problem the authors have created a 3D Photo Browser that puts thumbnail images of the photos in a 3D space that simulates the real outdoor site. When viewers want to see a photo they click on the corresponding thumbnail image and the original photo is displayed in a 2D window.

A number of photo browser using thumbnail images of stored photos have been researched. Some photo browser utilizes 3D virtual space for locating the thumbnail images, MIYOUE [2] is an example. The advantage of the proposed browser in this paper is that it uses the information of orientation and position of the photos to locate thumbnail images.

2. 3D Photo Browsing Space

For realizing the browser, there are two problems to be solved. The first is how to locate thumbnail icons in the stimulated 3D space. The second is how to represent thumbnail icons properly. This means the authors have to determine the positions and orientations of the cameras as well as the focal lengths of the cameras and the view angle of the photos.

2.1. Position and Orientation Determination

We know that at a specific point of time the relative position of the sun and the earth is specific. With the information on time and the location being observed, we can determine exactly the solar azimuth and solar altitude angles of the sun. The solar azimuth angle is the horizontal angle between the sun and the due-South or due-North vector (for this research the authors use the due-North vector), the solar altitude angle is the vertical angle between the horizontal and the line connecting to the sun. In the proposed system the authors define the world coordinate system with x axis as West – East, y axis as South – North, and the z axis upward with its origin is on the ground. The position of the sun on Gaussian sphere with radius 1 is determined through solar azimuth and solar altitude (Fig.1). If we call the world coordinates of the sun (X, Y, Z) then (X, Y, Z) are known.

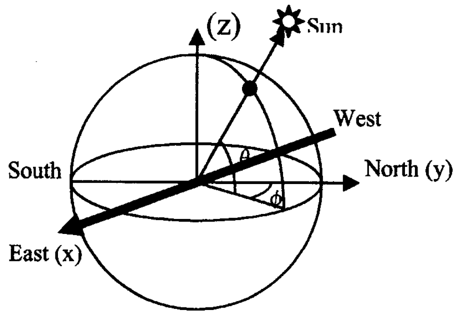

Figure 1: Sun position on Gaussian sphere with radius 1; ϕ is solar azimuth, θ is solar altitude

Furthermore we can use a 180 degree fisheye lens to take photographs of the sky. We use fisheye lens photo to determine the position of the sun on Gaussian sphere with radius 1.

If the fisheye lens camera rotates around x, y, z axes of the world coordinate system by the angles ψ, θ, ϕ respectively, we have the relationship between (x, y, z) and (X, Y, Z) as follows:

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} \cos\theta\cos\phi & \cos\theta\sin\phi & -\sin\theta \\ \sin\psi\sin\theta\cos\phi - \cos\psi\sin\phi & \sin\psi\sin\theta\sin\phi + \cos\psi\cos\phi & \cos\theta\sin\psi \\ \cos\psi\sin\theta\cos\phi + \sin\psi\sin\phi & \cos\psi\sin\theta\sin\phi - \sin\psi\cos\phi & \cos\theta\cos\psi \end{bmatrix} * \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \tag{1}$$

In this research the authors assume that the rotation angle around x axis is 0 ($\psi = 0$). So we have:

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} \cos\theta\cos\phi & \cos\theta\sin\phi & -\sin\theta \\ -\sin\phi & \cos\phi & 0 \\ \sin\theta\cos\phi & \sin\theta\sin\phi & \cos\theta \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \tag{2}$$

$$\Rightarrow \begin{cases} x = X\cos\theta\cos\phi + Y\cos\theta\sin\phi - Z\sin\theta \\ y = -X\sin\phi + Y\cos\phi \\ z = X\sin\theta\cos\phi + Y\sin\theta\sin\phi + Z\cos\theta \end{cases} \tag{3}$$

We can solve the equations (3) as follows:

$$\begin{cases} \phi = \arccos\left(\dfrac{y}{\sqrt{X^2+Y^2}}\right) - \arctan\left(\dfrac{X}{Y}\right) \\ \theta = \arccos\left(\dfrac{x}{\sqrt{K^2+Z^2}}\right) - \arctan\left(\dfrac{Z}{K}\right) \end{cases} \tag{4}$$

where $K = X\cos\phi + Y\sin\phi$

under the condition of (x, y, z) and (X, Y, Z) are coordinates on the Gaussian sphere with radius 1. This means the rotation matrix of the fisheye lens camera is determined.

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In the proposed system, the fisheye lens camera and a normal camera are fixed with 90 degree rotation around *x* axis (Fig.2)

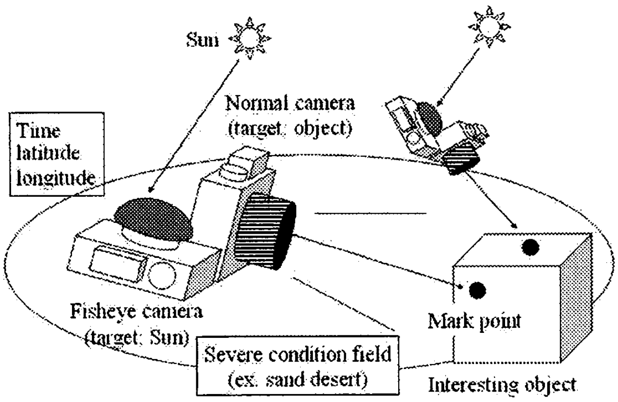

Figure 2: System configuration

We have the rotation matrix of the normal camera:

$$R = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & -1 & 0 \end{bmatrix} \cdot Q \tag{5}$$

where Q is the rotation matrix of the fisheye lens camera.

The relationship between coordinates of an object point in the world coordinate and homogeneous coordinates of its image expressed in terms of pixels:

$$\lambda \begin{bmatrix} x_i \\ y_i \\ 1 \end{bmatrix} = I_C \cdot \left(R \cdot \begin{bmatrix} X_W \\ Y_W \\ Z_W \end{bmatrix} + T \right) \tag{6}$$

where I_C is the intrinsic parameters matrix of the camera, and R and T are the rotation matrix and translation vector of the camera respectively.

Assuming that the height from the ground to the camera is fixed (at camera-man's height), the z component of the translation vector is known.

Using a mark point (its coordinates in a world coordinate system (X_W, Y_W, Z_W) and its image point coordinates (x_i, y_i) are given). From equation (6) we have:

$$T = \lambda \cdot I_C^{-1} \cdot \begin{bmatrix} x_i \\ y_i \\ 1 \end{bmatrix} - R \cdot \begin{bmatrix} X_W \\ Y_W \\ Z_W \end{bmatrix} := \lambda \cdot M - N \tag{7}$$

$$\Rightarrow \lambda = (T_3 + N_3)/M_3 \tag{8}$$

$$\Rightarrow \begin{cases} T_1 = \lambda * M_1 - N_1 \\ T_2 = \lambda * M_2 - N_2 \end{cases} \tag{9}$$

where T_i, N_i, M_i $(i = 1, 2, 3)$ denote the *i-th* component of vectors T, N, M

In this way, the translation vector is determined.

2.2. Thumbnail Icon Presentation

The appearance of a photo is determined by the focal length of the camera and the view angle, or we could also say that the appearance of a photo is determined by the focal length and the sensor size of the camera. To present thumbnail icons properly we have to depend on these parameters. By accessing EXIF [3] data of each image file we will get the value of the focal length, image size, digital zoom ratio, resolution of camera focal plane, and the unit of camera focal plane resolution (in inch, cm, ...). The size of the sensor can be calculated indirectly through the provided values.

3. Photo Browser

In the current browser a simulated 3D space is created and thumbnail images are put in this space with position and orientation depending on these data of the cameras. A user can rotate, zoom in, zoom out the space in order to view the scene from different directions, or click on a thumbnail image to enlarge it, the enlarged image is displayed in a new 2D window (Fig.3).

In the browser, distance from a camera to its thumbnail image is represented as a ratio with the value of focal length (FocalLength). View angles are determined depending on image size (ImageWidth, ImageHeight), digital zoom ratio when the image was shot (DigitalZoomRatio), resolutions of camera's focal plane (FocalPlaneXResolution, FocalPlaneYResolution) and the unit of camera's focal plane resolution (FocalPlaneResolutionUnit). These data are obtained from the EXIF data.

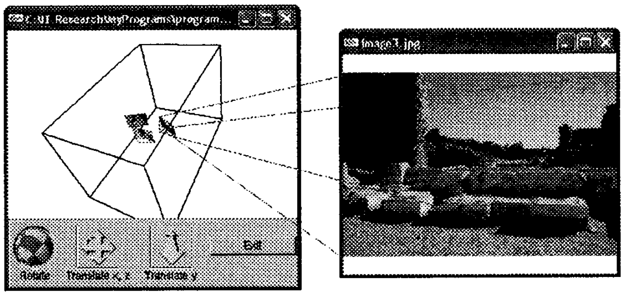

Figure 3: Screen shots of the browser,
(left) window containing thumbnail images,
(right) window displaying original photo

4. Conclusion

In this paper the authors introduce a simple method to determine orientation and position of a field camera. This method uses sun position, the height of camera position and a mark point as constraints. We also introduce the method of determining view angle using information obtained from EXIF data. These are the methods we use to develop a photo browser utilizing 3D space.

References

[1] Al Zayyan Temple 3D Measurement Project Egypt –Japan, http://www-sens.sys.es.osaka-u.ac.jp/egypt/top.html

[2] MIYOUE 3D photo browser, http://www.osl.fujisu.com/miyoue/download.html

[3] Exchangeable image file format for digital still cameras, http://www.kodak.com/global/plugins/acrobat/en/service/digCam/exifStandard2.pdf