단안렌즈 스테레오를 이용한 깊이 지도

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Depth Map Using New Single Lens Stereo

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요 약

논문에서 우리는 한 대의 카메라 전면에 위치한 4개의 거울을 이용한 실질적인 스테레오 비젼 시스템을 제안한다. 스테레오 이미지는 한 대의 CCD 카메라 정면에 위치한 4개의 거울을 이용하여 좌/우 이미지가 절반씩 만들어진다. 3차원 공간에서 물체 위의 한 점은 4개의 거울로 인해 2개의 가상 점으로 변환된다. 전통적인 스테레오 비젼 시스템과 같이 2개 가상 점이 위치한 좌/우 이미지 사이의 변위는 물체 위의 점에 대한 깊이와 직접 관련이 된다. 그러므로 이 시스템은 카메라가 한 대만 사용해 카메라 교정과 스테레오 이미지 획득에 큰 장점이 있다.

Abstract

In this paper, we present a novel and practical stereo vision system that uses only one camera and four mirrors placed in front of the camera. The equivalent of a stereo pair of images are formed as left and right halves of a single CCD image by using four mirrors placed in front of the lens of a CCD camera. An object arbitrary point in 3D space is transformed into two virtual points by the four mirrors. As in the conventional stereo system, the displacement between the two conjugate image points of the two virtual points is directly related to the depth of the object point. This system has the following advantages over traditional two camera stereo that identical system parameters, easy calibration and easy acquisition of stereo data.

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1. Introduction

The major methods of depth perception are stereo vision using more than two cameras, beam projection, moire and point projection. The establishment of correspondence from a pair of stereo image of the scene is generally thought to be the most difficult step and can become the most time-consuming.

Differences in the optical properties of the two cameras -focal length, zoom level and geometric difference between lens- cause the difficulty. To reduce these unwanted geometric and intensity differences and increase the ability to find correspondences reliably, single lens stereo vision has been studied.

Multi-focus camera method was proposed by Hiura and Matsuyama. They presented ideas for the practical DFD range sensor development. They introduce the multi-focus camera, a new image sensor for the DFD range measurement, which can capture three images with different focus values simultaneously. It is fabricated from an ordinary 3CCD video camera and outputs three defocused images to standard RGB

video channels respectively. And depth information is extracted from the three defocused images using DFD[1].

Nayar and Gluckman proposed single lens stereo with two mirrors. This system use only one camera and two mirrors placed in front of the camera. Although this system can obtain

stereo image by single shot, epipolar line has not same scan line[2].

Teoh and Zhang proposed a single-lens stereo camera system. The rotating mirror is made parallel to one of the fixed mirrors and an image is obtained. then it is made parallel to the other fixed mirror and another image is obtained. This camera system requires two shots from a scene and, therefore, should be used only in a static scene[5].

Single lens stereo with biprism was proposed by Doo Hyun and In So. This system use biprism in front of camera. but the sight of view of the system restricted by the distance between camera and biprism. However an additional advantaege of the geometrical set-up is that corresponding feature automatically lie on the same scan line like us[4].

A single camera system that can obtain images in a single shot and though a single lens was proposed by Gosthasby and Gruver. The reversed image should be transformed to appear as if obtained by cameras with parallel optical axes, before carrying out the correspondence and measuring th depth values from the correspondence[6].

In this paper, we present a novel and practical stereo vision system that uses only one camera and four mirrors placed in front of the camera. The equivalent of a stereo pair of images are formed as left and right halves of a single CCD image by using four mirrors placed in front of the lens of a CCD camera. An object arbitrary point in 3D space is transformed into two virtual points by the four mirrors. As in the conventional stereo system, the displacement between the two conjugate image points of the two virtual points is directly related to the depth of the object point.

We can apply flexibly distance between camera and object because it can move to parallel mirrors each other. Also, we can seek easily epipolar lines because this system is made by identical angle with camera. This system, therefore, has the following advantages over traditional two cameras stereo that Lens, CCD and digitizer parameters are identical for the stereo pair images having identical system parameters facilitates stereo matching. Because only a single camera and digitizer are used, there is only one set of intrinsic calibration parameters. Camera synchronization is not an issue because only a single camera is used.

2. Geometry

A stereo view like conventional stereo can captured by the single lens stereo with mirrors. First we place prependicularly four mirrors in front of CCD camera. A scene reflected by left and right mirrors is projection to one image plane. So there is no need for the normalization of image intensities.

The fig. 1. shows the formation of the image by the single lens stereo vision with mirrors. The camera coordinate system (x, y, z) has the image plane coincident with the xy plane and the optical axis along the z axis. Thus the center of the image plane is at the origin, and the center of the lens is at coordinates(0, 0, λ). A point P(Xp, Yp, Zp) is projected to two image point m1 (x1, y1), and m2 (x2, y2) by mirrors, M1, M2, M3, M4.

An arbitrary point P(Xp, Yp, Zp) in 3-D space is transformed into the two virtual points P1(X1, Y1, Z1) and P2(X2, Y2, Z2) by the four mirrors. That is, an object point in 3-D space is transformed into the two virtual points. A lens gathers all the light from the two virtual point P1 and P2, and creates two corresponding image point m1 and m2. The geometric relationship between the 3-D point P and the two

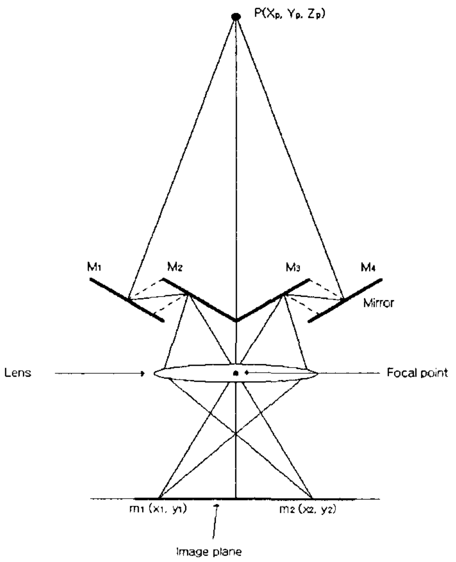


Fig. 1. The geometry of the stereo with mirrors.

virtual 3-D point P1 and P2 ,can be represented by simple transformations:

$$P1 = V1P \quad \cdots\cdots (1)$$

$$V_1 = \begin{bmatrix} 1 & 0 & -tna\,\theta_1 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad V_2 = \begin{bmatrix} 1 & 0 & -\tan\theta_2 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$P2 = V2P \quad \cdots\cdots (2)$$

From equation (1) and (2), we can see that the world point P moves by Xp-tanθ1Zp, P1 and Xp+tanθ1Zp to x axis. Let us define the disparity of the biprism as t도 translation distance between the two virtual points. From equation (1) and (2),

$$D = X_2 - X_1 = Z_p(\tan\ \theta_2 - \tan\ \theta_1) \quad \cdots\cdots (3)$$

From equation (3), the distance between the two virtual points be larger as a world point moves farther away from the mirrors. Therefore, we can obtain the scene depth, given the distance between the two transformed points. To define the distance between the two virtual points as a function of the disparity on the image, we can get equation (4)and (5), from perspective projection of the two virtual points,

$$x_1 = \frac{X_1}{Z} + \lambda \quad \cdots\cdots (4)$$

$$x_1 = \frac{X_1}{Z} + \lambda \quad \cdots\cdots (5)$$

$$Z = Z_p + \lambda \quad \cdots\cdots (6)$$

3. Equivalent Stereo

It is easy to reconstruct equivalent stereo system to a single lens stereo with mirrors system from the location of mirrors

A 3-D point P in the world coordinate system is projected to a image plane through focal point f. If there is no mirrors, the 3-D point P would be through a virtual focal point v. In Figure 3, the geometric relationship between the 3-D point and the virtual point v can be represented by the matrix A which convert a point to a symmetrical virtual point to mirror.

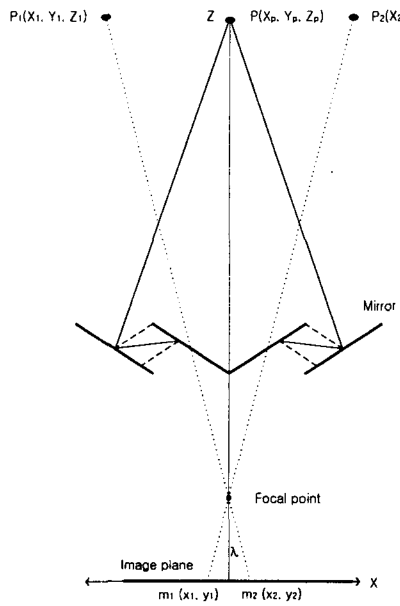


Fig.2. The relationship between real point and virtual point.

$$v = Af \quad \text{.......... (7)}$$

As a single lens stereo vision system with mirrors use four mirrors, each of them make the angles of $\delta 1$, $\delta 2$, $\delta 3$, $\delta 4$ to Z axis. So we can construct geometrical relationship between the mirrors and CCD camera like Fig. 4.

The matrix A contains sub_matrix AM3, AM1 which convert a point to a symmetrical virtual point to mirror M3, M1.from equation (7),

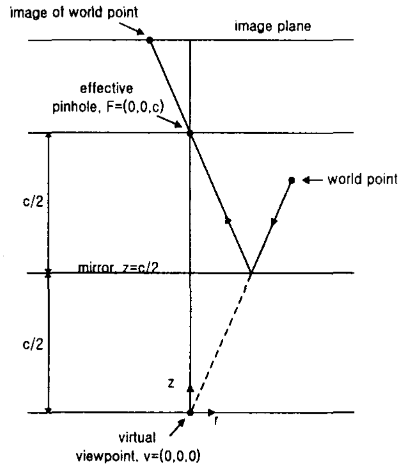


Fig. 3. The plane z = c/2 is a solution of the fixed viewpoint constraint equation[3].

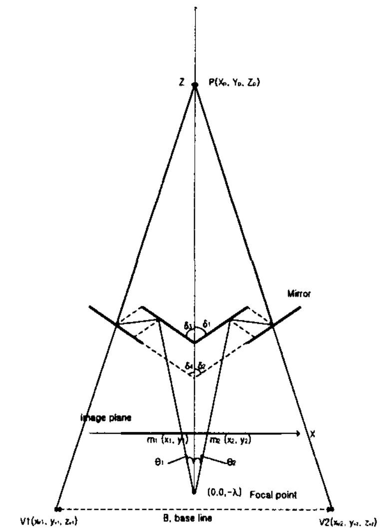


Fig. 4. The equivalent stereo system to the single lens stereo with mirrors.

$$V1^* = AM3F, \; V2^* = AM1F \quad \text{.......... (8)}$$

$$\begin{aligned} V1 &= AM4V2^* = AM3AM4F, \\ V2 &= AM2V2^* = AM1AM2F \end{aligned} \quad \text{.......... (9)}$$

The matrix A is of a translation matrix M, a rotation matix R by angle δ, a symmetrical matrix to Z axis T , a rotation matrix R' by angle $-\delta$ and a translation matrix M' which moves a mirror to original position.

$$AM1 = M'R'TRM = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \sin^2\delta - \cos^2\delta & \pm 2\sin\delta\cos\delta & (\cos^2\delta - \sin^2\delta)y_m - 2z_m\sin\delta\cos\delta + y_m \\ 0 & \pm 2\sin\delta\cos\delta & 0 & (\sin^2\delta - \cos^2\delta)z_m - 2y_m\sin\delta\cos\delta + z_m \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (10)$$

$$A = A_{M1}A_{M2} = M'R'_{\delta 1}TR_{\delta 1}MM'R'_{\delta 2}TR_{\delta 2}M \quad (11)$$

$$A = A_{M3}A_{M4} = M'R'_{\delta 3}TR_{\delta 3}MM'R'_{\delta 4}TR_{\delta 4}M \quad (12)$$

3. Experimental Result

In this section We present some result image which are computed from correspondences. And depth map from input image. Fig. 5 show a single lens stereo with mirrors. To abtain a stereo image, four mirrors is placed in front of a camera as shown in Fig. 5. A single lens stereo vision with mirrors use four prism mirrors and sticking system to maintain horizontality. The angles of $\delta 1$, $\delta 3$ are 45 ° and $\delta 2$, $\delta 4$ are 43 °.

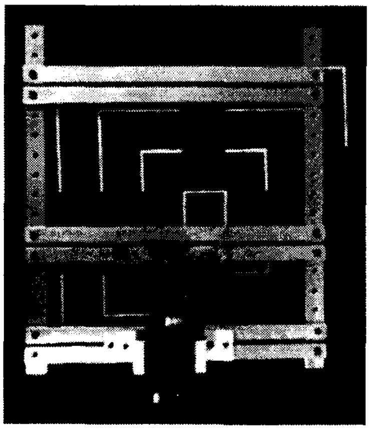


Fig. 5. Single Lens System with Mirrors

A simple cross-correlation technique is used for matching. For the experiment, 8×8 window to compute the sum of squared differences is used. Figure 6 and Figure 7 show an input image and corresponding features.

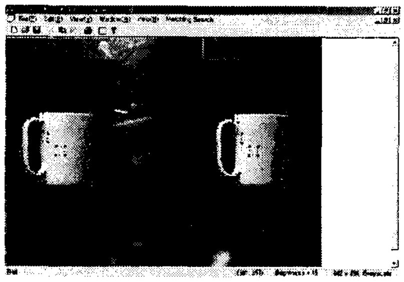
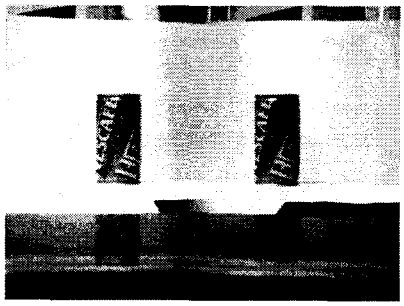
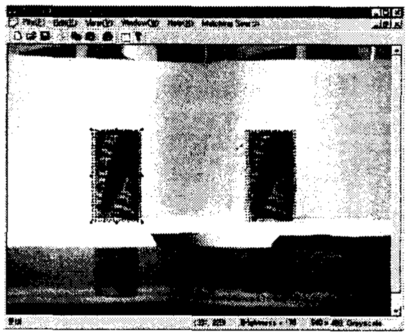


Fig. 6. The recovered corresponding points of image by cross-correlation algorithm

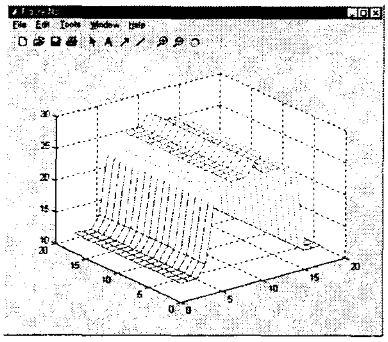


(a)



(b)

Fig. 7. Shows a disparity map computed from the single lens stereo with mirrors, which are computed for correspondences found automatically in a single lens stereo vision with mirror image. To obtain stereo image the mirrors are placed in front of a camera as shown in fig. 5.



(c)

Fig. 8. A disparity map from the single lens stereo vision with mirrors. (a) An input image (b) The computed orresponding features. (c) The computed disparity map.

4. Conclusion

In this paper, we present a single lens stereo vision with mirrors which can obtain a single image equivalent to two images obtained from two perfectly aligned cameras with exactly the same optical properties. This properties save time consuming of calibration and give easy extraction corresponding point. Calibration and 3-D reconstruction for a single lens stereo vision with mirrors is underway.

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