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Generation of Transition Views for Object Movie*

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Abstract

A transition views generation algorithm for object movie systems is proposed in this paper. The proposed algorithm generates transition views from two adjacent object images. First, we apply prewarping procedure to warp adjacent images such that the image planes of both images are parallel, then the system semi-automatically estimates the corresponding point for each pixel in both images. After the correspondences have been estimated, the morphing and correcting procedures are applied to the generate transition views. Finally, The postwarping procedure is used to generate object surround views instead of the lateral views generated by morphing procedure. The proposed technique can let object movie system browsing an object from less surround images, typically 8 to 24 images, and let users examine objects more smoothly.

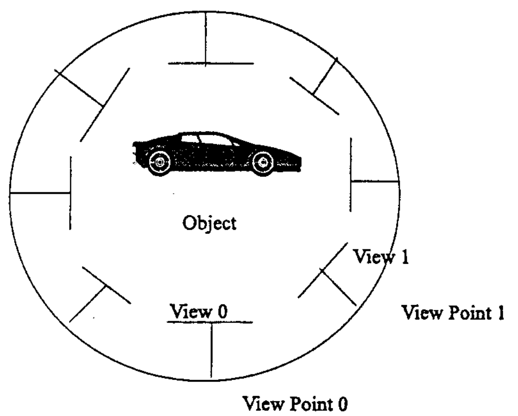

Figure 1: This figure illustrates the surround views for the object movie system.

1 Introduction

Object movie system is one of the important image-based virtual reality systems[1, 2, 3]. The object movie system can let users examine an object from almost arbitrary direction. However, traditional object movie system must capture many images for an object to provide surround views, typically 72 images for single directional rotation views and thousands of images for two directional rotation views. The manipulation and transmission of large amounts of images have becomes the obstructions when making the object movie system popular.

In this paper, we propose an algorithm, called the disparity morphing, to generate the transition views from two adjacent views. First, we apply prewarping procedure to warp adjacent views to be parallel, then estimate the correspondence for each pixel in both images. After the correspondences have been estimated, the morphing and correcting procedures are applied the generate transition views. Finally, a post warping procedure is used to generate object surround views instead of the lateral views generated by morphing procedure. The proposed technique can let object movie systems browsing an object from less surround images, typically 8 to 24 images, and let users examine objects more smoothly.

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2 Previews and Motivations

This section briefly introduces the concept of the morphing technique. Morphing technique contains two transition functions for each corresponding pair in the source object and the target object. One is the forward transition function, which defines how the corresponding point moves from the source object to the target object. The other is the backward transition function, which defines how the corresponding point moves from target object back to the source object. The forward transition function generates an intermediate object from the source object, and the backward transition function generates an intermediate object from the target object. In both functions, there are a variable s varying from 0 to 1, which determines that the intermediate object is how far away from the source object. When s is 0, the position of intermediate object is the same as that of the source object. When s is equal to 1, the position of intermediate object is the same as that of the target object. The corresponding pairs of the forward transition function need not to be the same as those of the backward transition function. Morphing technique also contains an interpolation function, which determines how the intermediate objects of the forward and backward transition functions are merged into resulted transition objects.

The image morphing[4], in which the "object" is equal to an image, is able to be applied to the image-based rendering systems. The image morphing contains a set of functions which morph each pixel from the source image to the target image. However, traditional image morphing function is usually a linear transition function of 2D image positions. If we simply apply the image morphing to an image-based virtual reality system, the generated transition views may not be the same views the viewers can see when they walking from the source viewpoint to the destination viewpoint in the real world.

The view morphing[5] technique was proposed to generate realistic transition views for image-based virtual reality system. View morphing contains three steps to complete its work described as follows.

The first step of view morphing is prewarping. The fundamental matrix[6, 7, 8] for the positions relation of the camera when taking the source and target images is estimated from the corresponding features in the source and target images. Then the source and target images are warped onto parallel image planes, and both warped image planes are parallel to the transition baseline.

The second step of view morphing is to apply traditional image morphing with linear transition function on the warped images. After the transition images are generated by applying the linear image morphing, those images are then back projected to the image planes, such that the resulted images are almost the same as the images taken by camera moving from the original source position and viewing direction to the original target position and viewing direction.

The view morphing technique can generate realistic transition views from source and target images, so view morphing is suitable for image-based virtual reality system for solving some transition problems. However, the view morphing can not deal with object occlusion problem properly. Furthermore, the view morphing technique does not explicitly define how to deal

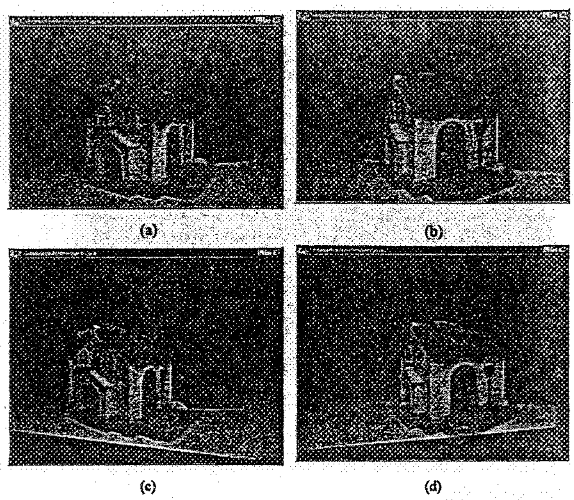


Figure 2: (a) and (b) show the original source and target images, respectively. (c) and (d) show the prewarped (parallel) source and target images, respectively.

with forward transition and corresponding points estimation problem, either.

In [9], we have proposed a new morphing technique, the disparity morphing, which can solve almost all problems for transition views generation for image-based rendering systems. In this paper, we apply the disparity morphing technique for object movie system to smoothly and realistically generate transition views between two object surround views. Furthermore, we will describe how to automatically estimate corresponding points pairs, and how to deal with the object occlusion problem.

3 Prewarping

Figure 1 illustrates the surround views for the object movie system. Now we want to generate transition views between each adjacent image pairs. For each adjacent image pair, we define the left-view image as source image, and the right-view image as target image. First of all, we need to warp the source image and the target image such that the original image planes are projected onto parallel image planes.

Figure 2(a) and figure 2(b) show the original source and target images, respectively. (c) and (d) show the prewarped (parallel) source and target images, respectively.

One method to perform the prewarping procedure is to use the fundamental matrix estimation algorithm[6, 7, 8] to estimate the fundamental matrix of two images, and then to warp both images based on the fundamen-

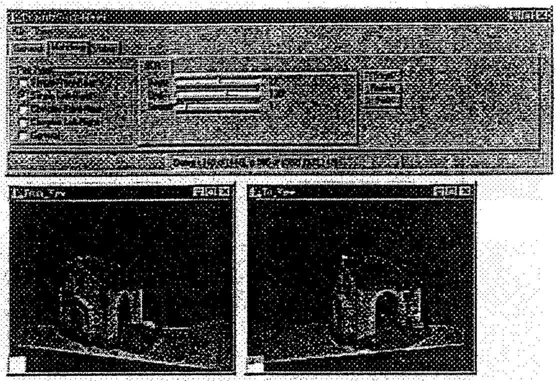


Figure 3: The overview of corresponding point estimation system.

tal matrix. However, the fundamental matrix is not easy to be automatically estimated robustly. In object movie system, the intrinsic and extrinsic parameters, such as the rotation angle between two adjacent images, are usually fixed and given. Thus object movie systems can prewarp those images to let them be parallel using given parameters directly.

4 Corresponding Points Estimation

After the source and target image pairs are warped into parallel planes, we can estimate the corresponding point for each pixel in both images by searching in horizontal direction.

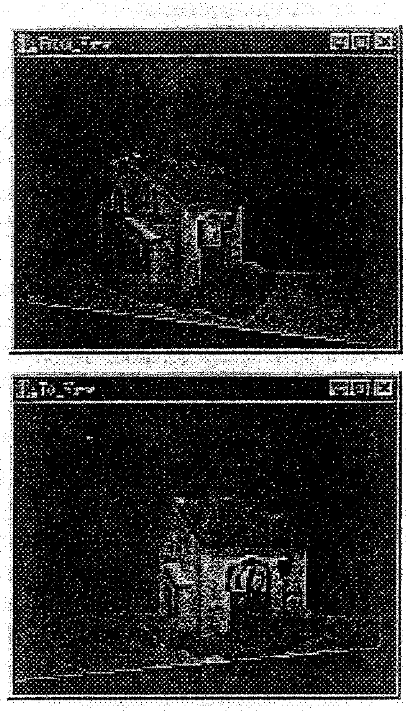
In our laboratory, we have developed a system to help on estimating the corresponding points for image pair. Figure 3 illustrates the corresponding point estimation system.

First, we apply block-matching technique with fast algorithm and horizontal search region to generate initial disparity maps. Figure 4(a) and figure 4(b) show the examples of corresponding points.

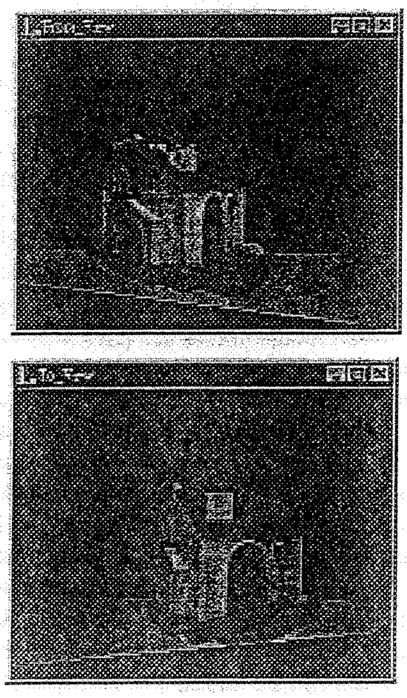
After the initial disparity maps generated by block-matching technique, the disparity maps are smoothed by minimizing the following energy function.

$$E = EI + s \times ED, \quad (1)$$

where E is the energy which we want to minimize, the EI is the sum of differences of the intensity for each corresponding pair, ED is the sum of the distances between the corresponding position of each pixel and the corresponding positions of its adjacent pixels. s is the smoothing factor, and is usually set as 1 in our experiments.



(a)



(b)

Figure 4: The examples of corresponding points after block-matching procedure.

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Figure 5(a) and figure 5(b) show the examples of corresponding points after minimizing the energy function.

5 Transition Views Generation

This section describes the disparity morphing algorithm. After the original images are warped to be parallel, we can apply the morphing function on the warped images. The morphing function used here is based on the estimated disparity maps. The disparity maps are estimated based on epipolar geometry as described in section 4. The function to morph the images is described in this section.

The morphing for lateral transition first prewarps the original source image and target image to be parallel to each other and perpendicular to the transition baseline as described in section 3. Figure 6(a) shows the original source and target image planes, and figure 6(b) shows the resulted image planes of the prewarping procedure.

As referring to figure 7, $\tan\theta_0$ and $\tan\theta_1$ can be estimated from disparity maps and intrinsic parameters of the camera. Then

$$\tan\theta_0 = \frac{B+BX}{BY} = \frac{1+X}{Y}, \tag{2}$$

and

$$\tan\theta_1 = \frac{BX}{BY} = \frac{X}{Y}. \tag{3}$$

From equations (2) and (3), X and Y can be calculated as equations (4) and (5).

$$X = \frac{\tan\theta_1}{\tan\theta_0 - \tan\theta_1} \tag{4}$$

$$Y = \frac{1}{\tan\theta_0 - \tan\theta_1} \tag{5}$$

Thus, $\tan\theta_s$ can be obtained from equation 6.

$$\tan\theta_s = \frac{(1-s)B+BX}{BY} = (1-s)(\tan\theta_0 - \tan\theta_1) + \tan\theta_1. \tag{6}$$

When the image planes are parallel to each other and to the transition baseline, the morphing function is a linear function of s, as shown in equation (6). However, for object movie system, what the users want to see is the transition views when they walk along arc A instead of the transition baseline, as shown in figure 8.

As referring to figure 9, let ϕ be $\angle PO_0O$, which can be obtained from fundamental matrix. For each point p_t at arc A, where t varied from 0 to 2ϕ indicates the length of arc O_0p_t, the corresponding point p_b lies on the transition baseline. Thus

$$\phi_t = \phi - t. \tag{7}$$

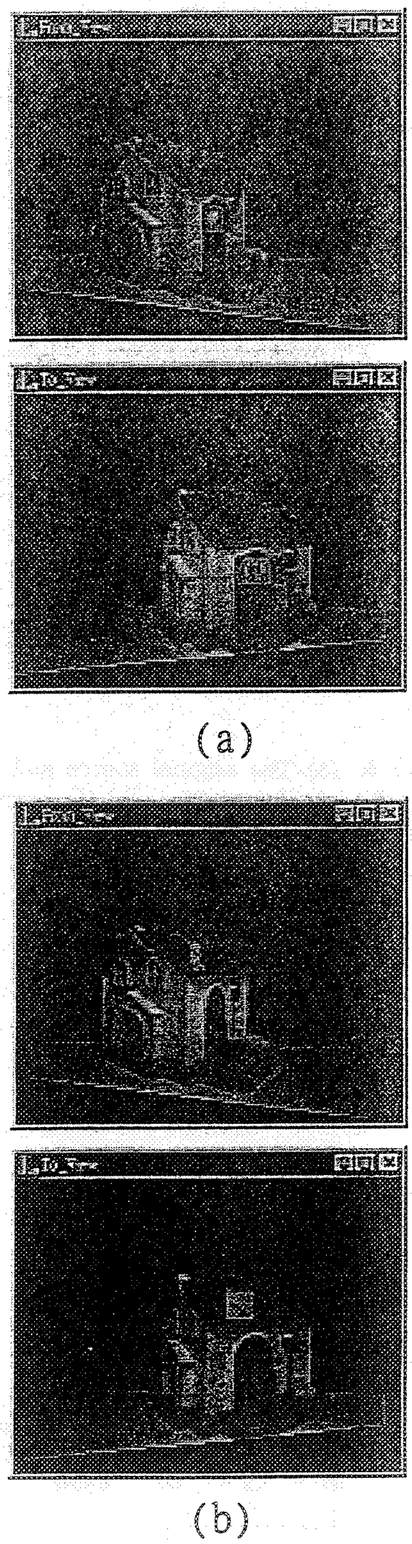

Figure 5: The examples of corresponding points after smoothing procedure.

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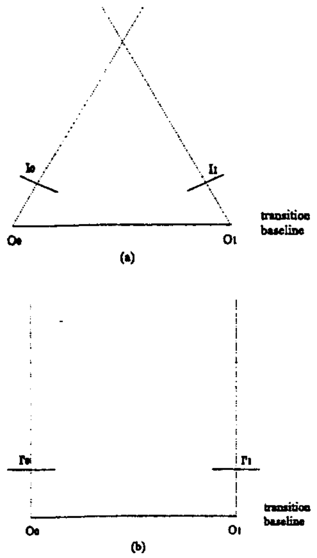

Figure 6: (a) The original source and target image planes for lateral transition, (b) the prewarped source and target image planes.

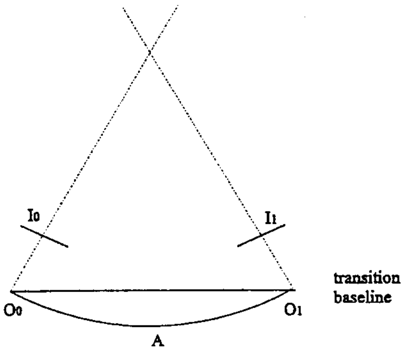

Figure 8: The viewing path, A, for generating an object movie.

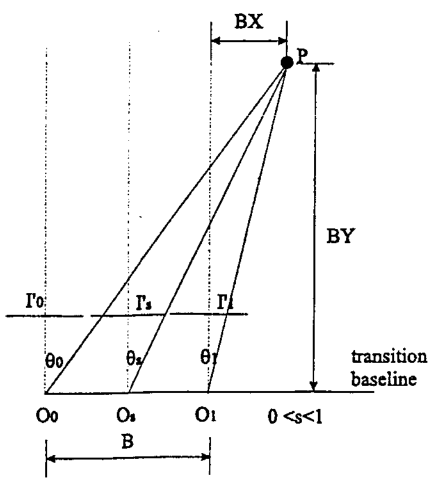

Figure 7: The morphing for lateral transition.

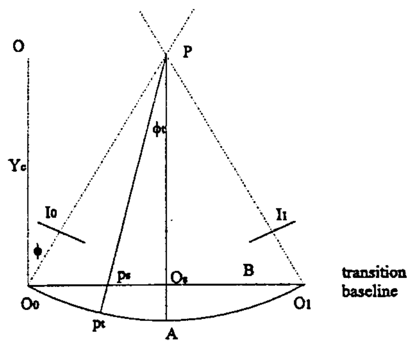

Figure 9: The morphing for generating object movie system.

Then

$$\overline{O_s p_s} = Y_c \tan^{-1} \phi_t = Y_c \tan^{-1} (\phi - t), \qquad (8)$$

and

$$\overline{Op_s} = \frac{B}{2} - Y_c \tan^{-1} (\phi - t) = Y_c(\tan \phi - \tan^{-1}(\phi - t)), \quad (9)$$

where Y_c can be obtained by applying equation (5).

After normalizing t and applied equation (9) to equation (6), the modified morphing function is shown in equation (10).

$$\tan \theta_s = (1 - (\tan \phi - \tan^{-1}(\phi - 2s\phi)))(\tan \theta_0 - \tan \theta_1) + \tan \theta_1 \quad (10)$$

The resulted image of equation (10) is the transition view on p_s. To approximate the transition view on p_t, the resulted image should be shrink by a zoom-out factor z_s, where

$$z_s = \frac{\overline{Pp_t}}{\overline{Pp_s}} = \frac{\cos(\phi - 2s\phi)}{\cos \phi}. \qquad (11)$$

The disparity morphing procedure performs the disparity morphing function for each corresponding point, and generates disparity flow for each corresponding point. Figure 10 shows an example of disparity flows. In this example, there is a background object from points p_1 to p_6 covered by a foreground object at points p_3 and p_4. Thus the points p_3 and p_4 move faster than p_1, p_2 and p_5, p_6. During the transition, for example $s = 0.5$, point p_3 and p_5 morph to the same image position. In traditional image morphing, the resulted pixel value usually is the weighted sum of the values of original points p_3 and p_5, and this method generates ghost effects on the resulted image. In the disparity morphing, the disparity of each corresponding point is examined to decide which point value should be output as the resulted pixel value. In this example, the disparity of point p_3 is larger than that of point p_5, that means the object at point p_3 is closer to the camera than the object at point p_5. Thus the pixel value of point p_3, the point with larger disparity, is output as the resulted pixel value. By applying this algorithm, the disparity morphing can deal with the object occlusion problem correctly, and can generate clear and correct transition views.

6 Postwarping

The resulted images of the previous morphing procedure are the transition views between two warped views. The postwarping procedure is applied to warp those transition views back to base on the original viewing directions. The postwarping procedure used here is also similar to that used in the view morphing technique, and please refer to [5].

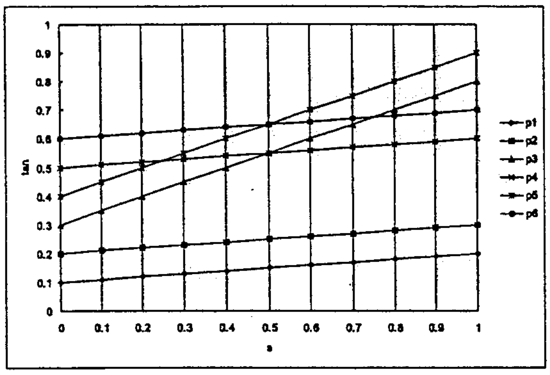

Figure 10: The disparity flows generated by the disparity morphing function.

7 Experimental Results

In object movie systems, the camera moves surrounding the object, and then takes a picture for each step. The disparity morphing function defined in equation (10) can be applied to generate smooth transition views. Figures 11(a)(c) and 11(b)(d) shows the original source and target images for rotating about 15 degrees and 45 degrees, respectively. Figure 12 shows the generated transition views for rotating 15 degrees. Figure 13 shows the generated transition views for rotating 45 degrees.

For the rotating 15 degrees example, since the view morphing has no explicit occlusion management mechanism, the ghost effect on the occluded pillar is significant during rotating the object, as shown in figure 12(b). For the rotating 45 degrees example, the view morphing generate fading in effect on the hidden wall as shown in figure 13(b). The disparity morphing can generate correct transition views on both cases.

The experimental results can be also examined at `http://smart.iis.sinica.edu.tw/~jet/html/objectdemo.html`, and the comparisons of disparity morphing and view morphing is also shown at `http://smart.iis.sinica.edu.tw/~jet/html/objectmore.html`. Comparing with the traditional object movie system, the disparity morphing can save a lot amount of image data, and generate more smooth object rotation views.

8 Conclusion

In this paper, we propose a new technique for generating the transition views for object movie system. We have developed a warping system for prewarping and postwarping the image pairs, a corresponding point estimation system for estimating corresponding points

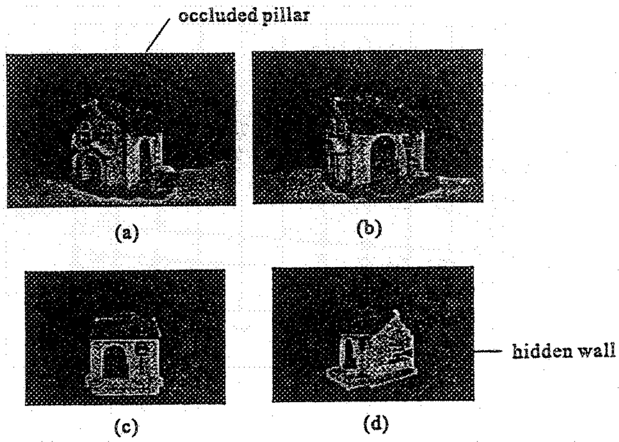

Figure 11: Disparity morphing for object movie system. (a) and (b) are the source and target images when rotating the object about 15 degrees, respectively. (c) and (d) are the source and target images when rotating object 45 degrees, respectively

and generating disparity maps, and a morphing system to generate transition views. Finally, we also develop a object movie system based on the transition view generation technique. By applying the proposed technique, we can save a lot amount of storage for object images, and can examine objects more smoothly than traditional object movie system.

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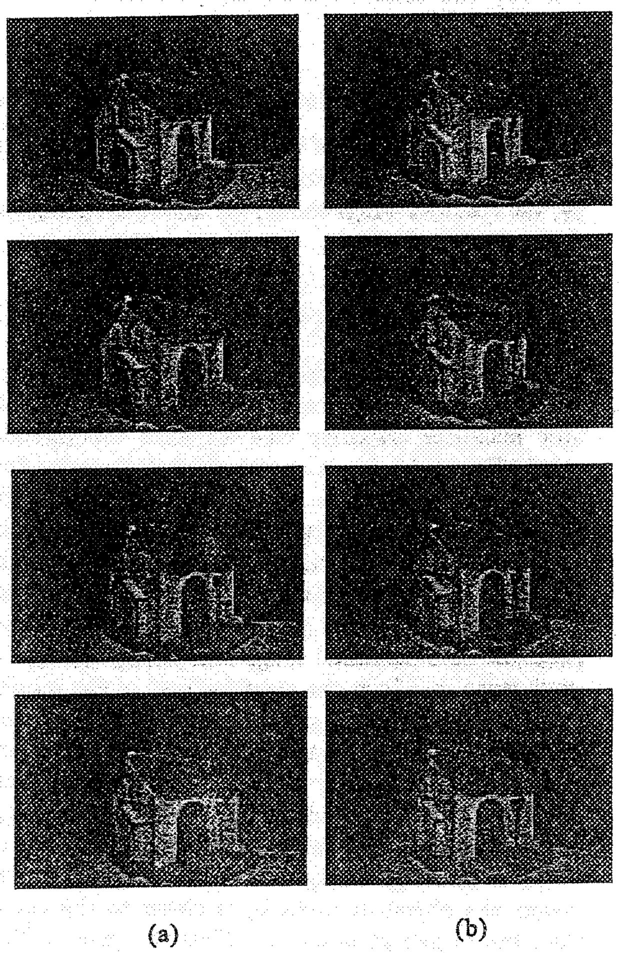
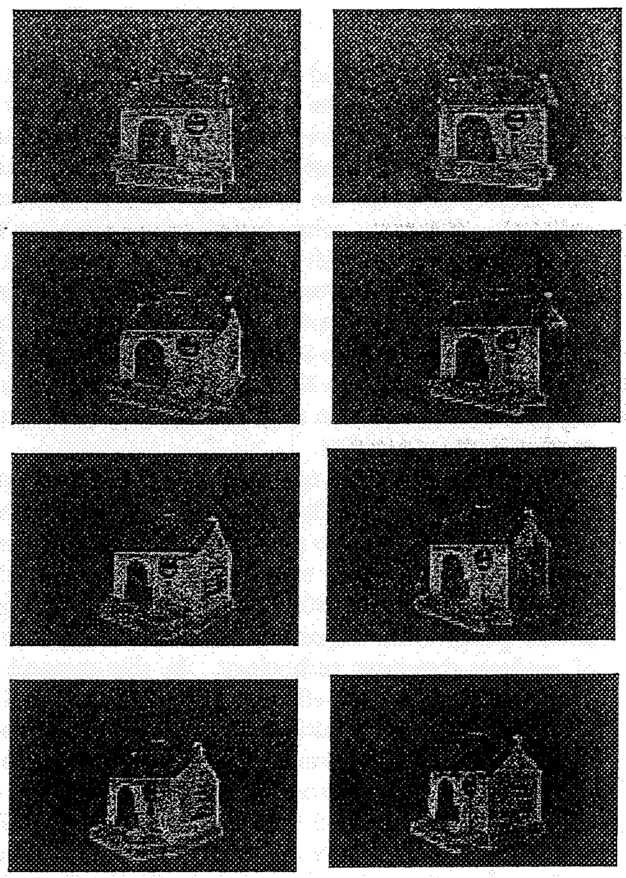


Figure 12: The resulted transition views generated by (a) disparity morphing and (b) view morphing techniques, respectively, for the rotating 15 degrees example.



(a) (b)

Figure 13: The resulted transition views generated by (a) disparity morphing and (b) view morphing techniques, respectively, for the rotating 45 degrees example.

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