32.2: A Real-Time 2-D to 3-D Image Conversion Technique Using Computed Image Depth

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Abstract

The "Computed Image Depth method" (CID) is proposed for converting from all kinds of two-dimensional (2D) images into three dimensional (3D) images. The 3D images are generated by computing the depth of each separated area of the 2D images with their contrast, sharpness and chrominance. The CID is implemented into a single-chip LSI with the "Modified Time Difference method" [1]. In this implementation, both methods are used adaptively according to the object's motions in the images. The 2D-to-3D image conversion system with this newly developed LSI realizes to generate 3D images automatically in real-time.

Introduction

Recently three-dimensional (3D) images have become more popular not only with the specialists but with the general people in the amusement parks. Furthermore, the word "3D" has been more popular by the Computer Graphics techniques such as the 3D games, the PC's video technologies, the 3D-CAD systems. In the CG techniques, it is realized to make of the 3D views for left and right eye easily. In contrast, it is difficult to get the 3D images in the real world, because a 3D camera is heavy to carry around and it is difficult to adjust the convergence, the sharpness and the zoom of the 3D camera. We thought that 3D business fields would expand if two-dimensional (2D) images could be converted into 3D images easily.

The 2D-to-3D image conversion technique using the "Modified Time Difference method" (MTD) had been developed in 1995.[1] The MTD allows to converting from 2D images into 3D images by selecting images that would be a stereo-pair according to the detected motions of objects in the input sequential images.

The 2D images that have the objects with the simple horizontal motion can be converted into 3D images by the MTD, but it is not good for converting from the still images or the images that have the objects with the complicated motions. So the new technique converting from these 2D images into 3D images is required.

The "Computed Image Depth method" (CID) has been developed to solve this subject. The CID allows to converting from all kinds of 2D images into 3D images. Especially the CID is suitable for converting from still images. The 3D images are generated by computing the depth of each separated area of the input 2D images with their contrast, sharpness and chrominance with the CID.

These techniques have been implemented into a single-chip LSI for the automatic and real-time 2D-to-3D image conversion.

Modified Time Difference method

Figure 1 shows how the MTD converts from 2D images into 3D images.

In the sequences of these 2D images, a bird is flying from the left to the right in front of the mountains. In this scene, if the fourth field of these images is given to the left eye and the second field is given to the right eye, the motion of the bird is perceived as the binocular parallax, whereby the bird can be seen as if it were popping out of the mountains. This technique is based on the principle well known as the Pulfrich Effect.

In order to adapt this technique to the automatic and real-time 2D-to-3D image conversion, we had developed the MTD. In the case such as figure 1, the images include the objects moving toward the horizontal direction. The result of analyzing the motion vectors that are detected from the input 2D images should decide the time difference between the left and the right eye images, and either eye that the delayed image is given to. So, the MTD is suitable for converting from the images with the simple horizontal-moving object such that the object spins or the object moves to the horizontal direction against the background. But the MTD does not

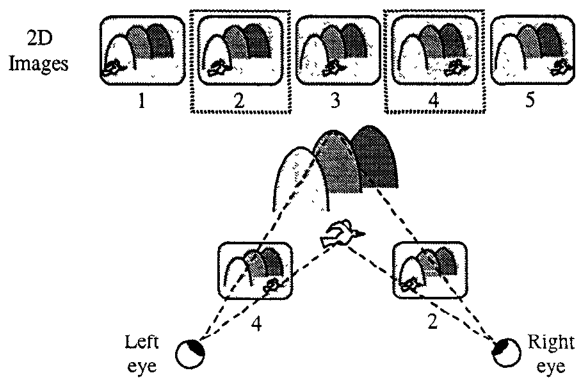

Figure 1. Principle of MTD

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work well for the images that have the objects with the complicated motions or no motion.

Computed Image Depth method

The "Computed Image Depth method" (CID) is proposed for converting from still 2D images into 3D images. When we watch a 2D picture, we generally recognize the far-and-near positional relationship between the objects in the picture by some information in it. These information are how the objects are covered each other, how sharp the images are, how much contrast the images have, what the images are, what the objects are, and so on. These information are supposed to be useful for the 2D-to-3D image conversion. So we use the sharpness and the contrast of the input images for computing the far-and-near positional relationship of the objects in the CID.

The CID consists of the following two processes. One is the image depth computation process that computes the image depth parameters with the contrast, the sharpness and the chrominance of the input images. The other is the 3D image generation process that generates the 3D images according to the image depth parameters. Figure 2 shows the basic principle of the CID.

At first, each sharpness, contrast and chrominance values of the separated areas in the input images is detected respectively. The sharpness means the high frequency element of the luminance signal of the input images. The contrast means the middle frequency element of the luminance signal. The chrominance means the hue and the tint of the color signal of the input images.

Furthermore, the adjacent areas that have close color are grouped according to the chrominance values. The image depth computation works to be based on these grouped areas.

The image depth computation process uses the contrast values and the sharpness values. Generally in the photographs and the TV images, the near-positioned objects have higher sharpness and higher contrast than the far-positioned objects and the background image. Therefore, these contrast and sharpness values are inversely proportional to the distance from the camera to the objects. If only these values are used for the image depth computation, it often occurs that the center of the images become nearer than both sides, top and bottom of the images. This cause is that the focused object is generally positioned at the center of the images, and the ground or the floor is positioned the bottom of the images that has flat surface generally and few contrast and sharpness values are taken from the bottom areas. So, it is adopted to compensate these values by the image's composition. The composition has the tendency that the center or the bottom side of the images is nearer than the upper side in the general images. So, each image depth parameter is decided by the average of each area's sharpness and contrast value that is weighted by the image's composition. This compensation would be better way to get good 3D effect, but it should be changed according to the applications.

Secondly, the 3D image generation process generates the left and the right eye images according to the image depth parameter of each grouped area. If the parameter of an area indicates near, the left images are

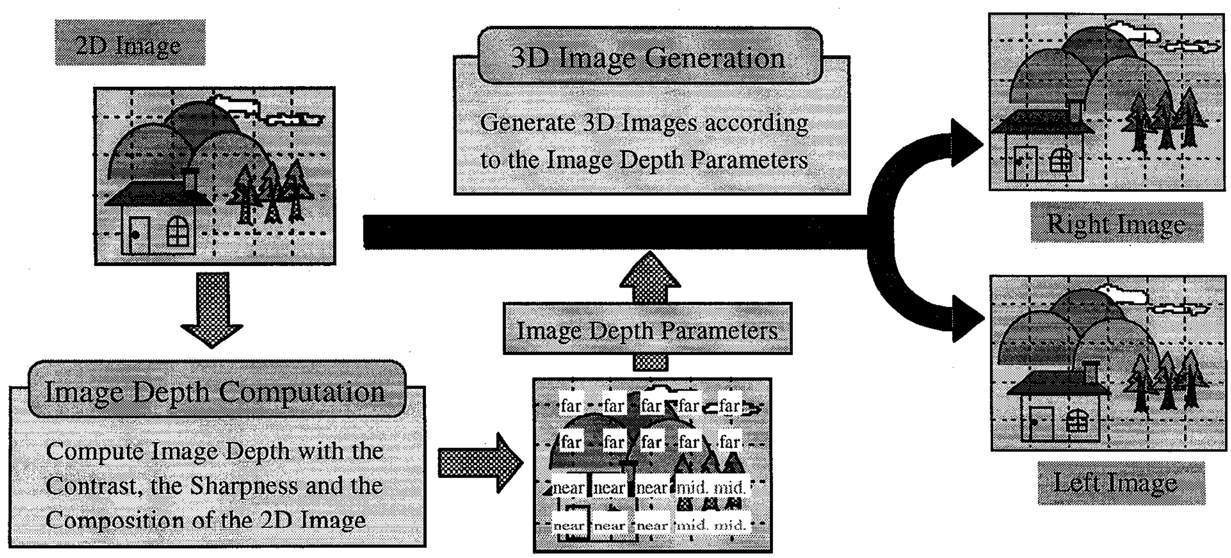

Figure 2. Principle of CID

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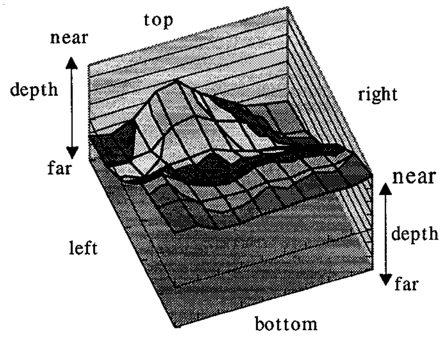
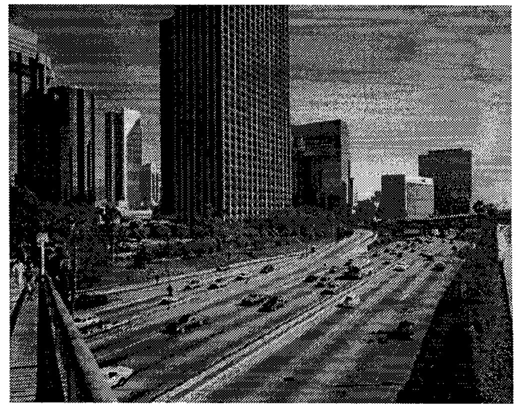


Figure 3. Image Depth Parameters of Picture 1



Picture 1. Sample Picture (Highway)

made by shifting the input images to the right, and the right images are made by shifting to the left. If the parameter of an area indicates far, both images are made by shifting to each opposite direction. The horizontal-shift value of each separated area is proportional to the 3D effect. Furthermore, when the image depth parameters are changed quickly or frequently, the converted images become hard to be watching. Therefore, each shift value is adjusted to decrease the quick changes of the image depth parameters between the adjacent areas. As a result of these processes, the 3D images that are easy to watch can be generated.

The CID is especially suitable for converting from still images, because it does not need any motions of the objects in the images. Of course, the CID can be also adapted for the images with moving objects.

Figure 3 shows the image depth parameters of Picture 1.

Adaptive Control of MTD and CID

The MTD has the feature that the converted 3D images from the images with the horizontal moving object have a stereo-occlusion. The CID has the feature that any image can be converted into 3D images, but the CID can not generate a stereo-occlusion yet. So, we propose the adaptive control between the MTD and the CID in order to improve the 3D effect of the converted images.

At first, each motion vector of the separated areas in the input images is analyzed. According to this analysis, if the input images have the simple motion suitable for the MTD, the MTD is used for the 2D-to-3D image conversion. In the other case, the CID is used. In the transition period between the MTD and CID, both methods are used to overlap to each other. So, the converted images have both good features of the MTD and the CID. If the decision that method should be used is changed suddenly, the transition between the MTD and the CID is controlled smoothly.

By the adaptive control, all of the images can be converted constantly into the impressive 3D images.

LSI Implementation

The new 2D-to-3D conversion LSI is implemented the circuits of realizing the automatic and real-time 2D-to-3D image conversion by the MTD and the CID. Figure 4 shows the system diagram of this LSI with the peripherals. In this LSI, the image characteristic detection circuit and the 3D image generation circuit are mainly implemented. The image characteristic

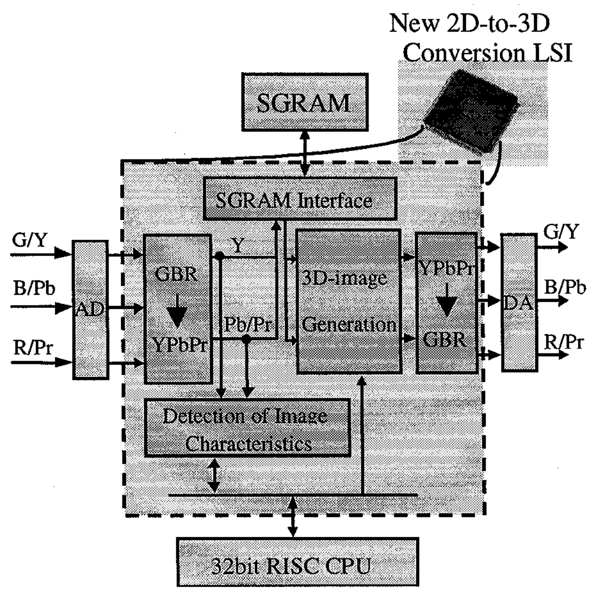


Figure 4. System Diagram of New 2D-to-3D Conversion LSI and Peripherals

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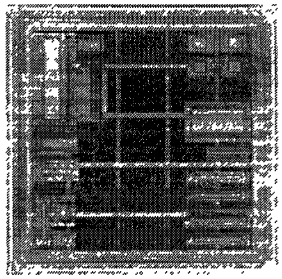
Process	0.35μm Triple Metal CMOS
Gate number	Approx. 300k Gates
Supply voltage	3.3 V
Package	QFP 240 pin

Table 1. LSI Specifications



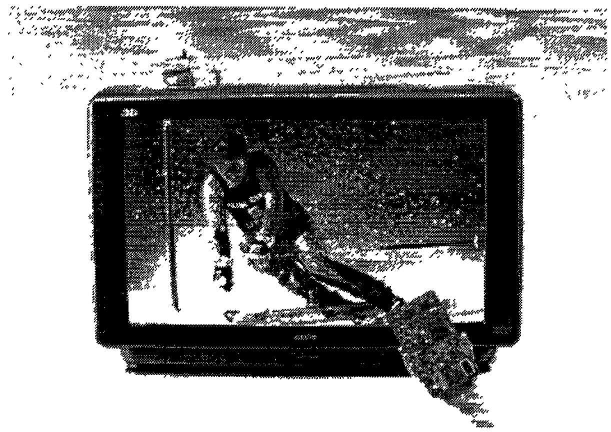
Picture 2. New 2D-to-3D Conversion LSI chip

detection circuit gets the sharpness, the contrast, the chrominance value and the motion vectors, and sends these data to the 32bit RISC CPU. This CPU calculates the image depth parameters for the CID and the time difference for the MTD, and sends them to the 3D image generation circuits in the LSI, and realizes the adaptive control between the MTD and the CID. SGRAMs are used for making the time difference of the MTD and the flicker-free 3D images (Field-frequency:120Hz) for the glass-use 3D TV described in the next section. Table 1 shows the specifications of this LSI, and Picture 2 shows the photography of the 2D-to-3D conversion LSI chip that is about 300,000 gates embedded array ASIC.

This LSI is designed to be applicable to various input sources such as NTSC, PAL, HDTV and PC graphics signals. This LSI has two kinds of the output signal format, one is the double scanned signal for the glass-use 3D TV and the other is separated signals of the left and the right images for the glass-less 3D display [3]. Furthermore, this implementation realizes to make the 2D-to-3D image conversion board compact and to reduce its cost.

2D-to-3D Conversion Board

The automatic and real-time 2D-to-3D image conversion board has developed for the demonstration of these newly proposed techniques. Picture 3 shows the flicker-free and the glass-use 3D TV with the 2D-to-3D image conversion board and the light-weighted LCD shutter glasses that is put on the TV. The conversion board size is 160 mm x 95 mm, and its power supply needs about 5W. The weight of the glasses is about 65g, and its IR-transmitting signal is coded for no interference of the fluorescent lamp.



Picture 3. 3D TV with 2D-to-3D Conversion Board

Conclusion

The new 2D-to-3D image conversion technique with the MTD and the CID realizes to convert any type of visual resources into the 3D images. Furthermore, the LSI implemented these methods provides 3D representation automatically in real-time. This LSI can process not only TV signals like NTSC, PAL and HDTV standards but PC graphics signals like VGA, SVGA and XGA. These features of this LSI bring up to expand widely to the application fields of the 2D-to-3D image conversion.

This new conversion technique realizes the increase of the 3D video programs, and allows people to enjoy 3D images in anywhere. These would open up new 3D business fields such as consumer, medical and entertainment.

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