PIXEL INDEPENDENT RANDOM ACCESS IMAGE SENSOR
FOR REAL TIME IMAGE-BASED RENDERING SYSTEM

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ABSTRACT
We have been investigating a high-speed image-based rendering system. In this area, most of the conventional systems sacrifice spatial or temporal resolution for heavy amount of input images. When the system uses the camera-array on its input, this problem is more obvious. However, required image data for the rendering are only a portion of them, determined by the position of the imaginary-view. In this paper, we propose the image based rendering system, which uses pixel independent random access image sensors to eliminate the bottleneck of the conventional systems. We have developed a prototype of CMOS image sensor, which has 128 x 128 pixels. We verified that the prototype chip readouts externally selected pixels at 60 frames /second.

1. INTRODUCTION
In the field of virtual reality, a new technique called image-based rendering has been proposed [1][2]. With this technique, imaginary-viewpoints-images can be synthesized from multiple sampled images. The most characteristic aspect of this method is that the imaginary-view can be obtained without having the geometric modeling of the objects. To date, one image-based rendering system can achieve 30frames / second with 4×4 image inputs, using the texture mapping function of SGI- Onyx2™ [3].

However, most of the conventional image-based rendering systems, including [3], work under sacrificing the spatial or temporal resolution due to the heavy amount of data on their inputs.

On the synthesis procedure of imaginary-view, certain part of multiple-images are selected and used according to the position of desired-viewpoint. Since only a portion of image data are needed by the rendering, the amount of readout date could be remarkably reduced if each of the image sensor outputs the externally selected pixels only.

We designed a new CMOS image sensor, which has the capability of pixel-based random readout operation. In this paper, we describe the design, implementation and the evaluation of the sensor.

2. IMAGE-BASED RENDERING
Among the several methods of the image-based rendering, we use light-ray data space rendering method to provide the 3-D imaginary viewpoints from the 2-D array of images. Figure 1 shows an example of position between the imaginary-camera, the real-cameras and the objects. In Figure 1, real-cameras are aligned to the plane of Z=0. The imaginary-camera can move not only X-Y directions, but also Z direction.

In the light-ray data space rendering, all of the image data is regarded as a set of light ray data. Synthesis of the
imaginary-camera-view has been done by sampling the closest light ray from the real-camera array. Figure 2 shows the basic concept of the light-ray data space rendering. First, decide the view area of the imaginary-camera. Second, select the real-camera, which is nearest to the ray between objects to the imaginary-camera. Then select and sample the closest light ray from the real-camera.

Figure 2. Basic concept of the light-ray rendering

Figure 3 shows the simulation result of the light-ray rendering. The source images are subset of “Multi-view-image database of Tukuba Univ.”. X, Y, Z axes are arranged as shown in Figure 1. Other simulation parameters are described in Table 1. Figure (a), (c) shows the input images. Figure (b) shows the imaginary-camera-view of (0, 0, 140). Figure (d) shows the imaginary-camera-view of (20, 20, -20).

Table 1. Simulation parameters

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<tr>
<td>Real cameras</td>
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<tr>
<td>Real camera separation</td>
<td>20[mm]</td>
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<tr>
<td>Real cameras to objects</td>
<td>700[mm]</td>
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<tr>
<td>Horizontal view area</td>
<td>27[degree]</td>
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<tr>
<td>Vertical view area</td>
<td>20[degree]</td>
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3. LIGHT-RAY RENDERING SYSTEM WITH RANDOM ACCESS IMAGE SENSOR ARRAY

Considering about the light-ray data space rendering, all the image data needed by processing, are only a portion of data taken from the real-camera array. But, according to the position of the imaginary-camera, that portion changes from frame to frame.

Figure 4 shows the new light-ray rendering system, which we propose. The real camera array consists of random accessible image sensors and one control circuit. The control circuit is responsible for the translation from the imaginary-camera’s position to the real-camera’s address. Each camera does not have this function and outputs externally selected pixels only. Since every pixel value has at least 8 bits of data, address data are rather small compared to the pixel value data. Thus, the proposed system can be operated in higher frame rates or with much more quantities of cameras. In addition, the pixel value data output from the camera array is necessary and sufficient for the rendering, so the synthesized image data can be directly displayed without further processing.

In order to synthesize the imaginary camera’s view, the camera array should satisfy the geometric condition with
high accuracy. But the practical cameras have many distortions. For instance, each camera has some irregularity of optical axes and the distortions from the lenses.

To suppress these distortions, address data should be calibrated beforehand, and calibration data are stored in EEPROM. When the distortion is complicated as shown in Figure 5, the pixel-independent selection is necessary to adjust them.

The former method is superior in the turn-around time but the number of the control signals increase, along with the pixels. The latter method doesn’t have this problem while the control timings are rather strict. The parallel addressing method is appropriate for the small number of pixels. And the skip scanning method is suitable for the large number of pixels. The designed chip can handle both of the methods. To keep the same integration time, designed sensor has the sample & hold circuit in each pixels.

Figure 7 shows the circuit of the smart shift register that we adopt. This shift register consists of the CMOS dynamic shift register and the output control memory. When the memory value is 1, then the shift pulse goes through the upper path and output the corresponding pixel value. But, when the memory value is 0, then the pulse goes through the lower path and skip reading the corresponding pixel. The pixel independent readout function can be achieved in this way. The values of the output control memories should be written proceeding to the reading line, by 1 horizontal scanning period.

We have developed the prototype of pixel-based random access sensor, which has 128 x 128 pixels. Figure 8 shows the prototype chip, detailed chip parameters are shown in Table 2.

<table>
<thead>
<tr>
<th>Table 2. Prototype chip parameter</th>
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<tbody>
<tr>
<td>Number of pixels</td>
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<tr>
<td>Chip size</td>
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<tr>
<td>Pixel size</td>
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<tr>
<td>Fill factor</td>
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<tr>
<td>Number of transistors</td>
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<td>Process</td>
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5. EXPERIMENTS

Figure 9 shows the output images obtained by the prototype chip. Figure 9(a) shows the output image of entire pixels on the focal plane at 60 frames /second.

Figure (b) shows the selected output by using the smart shift register. The selected region is the square shaped area, in the middle of the image (40<x<90, 40<y<90). Because of the skip scanning of the smart shift register, the output sequence has no margins on the top and the left.

Figure (c) shows the selected output by using the parallel addressing method. The selected region is (40<x<90, 40<y<90). In this experiments, addresses are input from the data generator (Tektronix, DG-2020), one pixel to another.

From the three pictures of Figure 9, the prototype chip can be verified to work properly.

11. REFERENCES


