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3-D Binocular Range Sensor LSI with A High-Speed Data Output Method

Norihito KAWAGUCHI[1], Masatomo KAWANO[2], and Yutaka ARIMA[1]

[1]Center for Microelectronic System, Kyushu Institute of Technology
[2]Fukuoka Industry, Science & Technology Foundation
[1]680-4, Kawazu, Iizuka, Fukuoka 820-8502, JPN
TEL: [1]+81-948-29-7590, FAX: [1]+81-948-29-7586, E-Mail: [1] n-kawaguchi@cms.kyutech.ac.jp

1. Introduction

Recently, high speed 3-dimensional obstacle detection devices are being developed to prevent traffic accidents and automate security systems. We developed a binocular range sensor LSI to achieve a low cost obstacle detection device. We achieved a low cost and small size obstacle recognition system by integrating two image sensors and their parallel processing circuits on a single chip [1][2].

Also, we had previously developed a binocular range sensor LSI that can successfully detect various 3-D objects [3]. However, the output time for the 3-D data of one frame takes 26m sec. Therefore, it has a limited frame rate of 38 frames per second. In order to reduce the output time, we equipped the sensor LSI with a new high speed data output method.

2. Chip Level Configuration

Figure 1 shows a microphotograph of the developed chip. The chip was produced using a process of 0.35μm CMOS 1-poly 3-metal and has a die size of 4.20mm × 3.33mm.The sensor LSI is composed by two image sensors, 2 sets of 128 APWC (Analog voltage to Pulse Width Conversion) circuits, difference circuits, ICC (Invalid Correlation Canceling) circuits, 2 sets of 256 DSWM (Differential Signal Width Modulation) circuits, a matrix of 128 by 127 of correlation circuits and high-speed data output circuits. The left and right image sensors have an array of 128×16 pixels each. We are able to obtain information of the 3-D position of multiple objects by processing the output data of those pixels. The 128×127 correlation circuit matrix matches and measures, at the same time, the coincidence degree of all the differential outputs of 1 line of photosensors in the left and right image sensors. That coincidence value is stored as a charge on a capacitor in each correlation circuit.

In previously developed range sensor LSI [3], the data that is hold in the correlation circuit is read by the horizontal and vertical scanners one value at a time. When the output of the 128×127 elements of the correlated data is finished, the next line of photosensors' output is processed. This operation is repeated 16 times. Thus, 128×127×16 clocks are needed to read out the output of all the 3-D correlation data. Therefore, at a clock frequency of 10MHz the output time is 26msec. The maximum frame rate is 38 frames per second.

3. High-Speed Data Output Method

To reduce the output time of the sensor LSI, the output circuit was modified and the amount of data was reduced. In the proposed method the chip reads out only the address of the circuits where the stored correlation value exceeds a threshold value, instead of reading all the correlated value outputs. In other words, this method uses the correlated place information that points out the position of a detected obstacle. The output time can be reduced by using the proposed method. Under typical conditions, it is more than 10 times faster than the conventional output method.

Figure 2 shows the output circuit that uses the proposed method. This output circuit is composed by 127 I/V (Current-Voltage) converter circuits, comparators, 2 sets of 127 selectors, 128 shift registers and a 128-input 7-output encoder.

The operation of the output circuit is as follows. The horizontal shift register selects a column of correlated circuits. The data stored in the capacitors passes through the I/V converter circuit and each row data is introduced in parallel into the comparator. The comparator output is "High" if the input voltage is higher than a threshold voltage V_{ref} , otherwise the output is always "Low". The output of the comparator is fed to the two selectors, which are located between the shift registers. When the comparator's output is "Low" the shift register makes a short circuit and the shift operation for that row is omitted. The output of each shift register is connected to the encoder. Only the shift operation of the shift register corresponding to the comparator's "High" output occurs. Through this operation, the vertical addresses are gradually outputted. After the vertical data output is done, the stored values of the next column of correlated circuits are processed. This operation is repeated 128 times. The horizontal address is determined by counting from the address at the beginning of the vertical scanning.

4. Measurement Result

Figure 3 shows the output result of the 7th line of photosensors. Figure 3(a) shows the output result of the conventional chip. Figure 3(b) shows the output result using the proposed method. The addresses corresponding to the object's position are displayed as points.

Figure 4 shows the result of an experiment using 2 target objects. We can see that the position of the three dimensional Object A and Object B are correctly detected.

In the experiment, the correlation process and the ICC process for one line of photosensors takes 1μsec each. The output process for all the 16 lines takes 32 μsec. The output time for the all 3-D correlated addresses is 240 μsec. As a result, the total time for 1 frame is 272 μsec. The photosensors' charge accumulation and all the processing is done at the same time. Therefore, we can achieve an output of 3676 fps. The output time varies according the exposition time and the total number of obstacles.

The chip uses a 3.0V supply voltage and has a power consumption of 405 mW at a clock frequency of 10 MHz.

5. Conclusion

We developed a 3-D binocular range sensor LSI with a high-speed output circuit. We confirmed a reduction of the time for one frame. When two 3-D objects were detected, the output time for one frame was 240 µsec. The frame rate was practically not limited by the data output time using the proposed method. We expect that the application range of the binocular image sensor can be expanded by this improvement in the output speed.

Acknowledgement

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References

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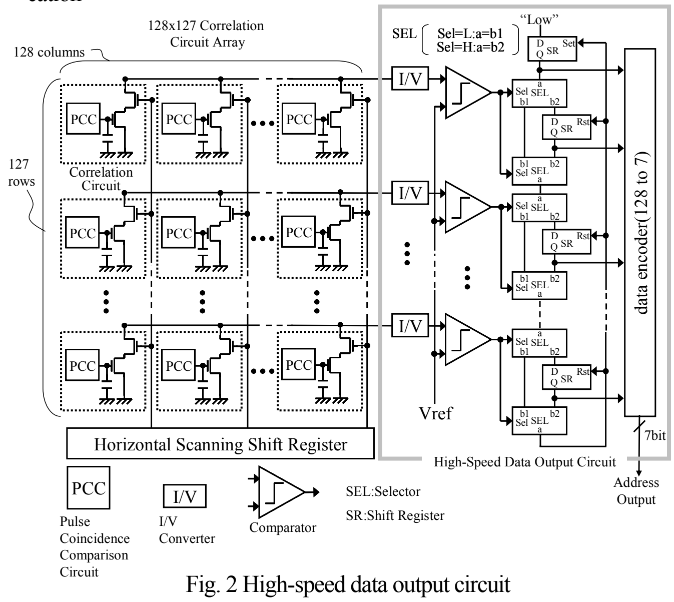


Fig. 2 High-speed data output circuit

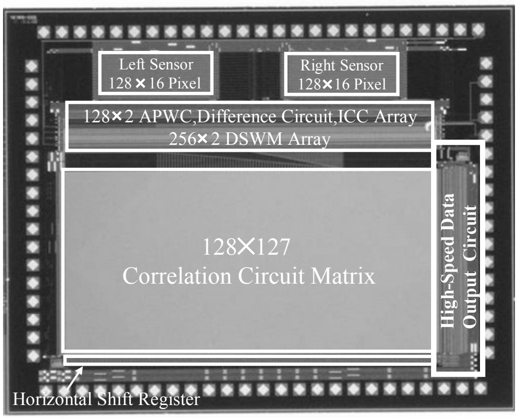
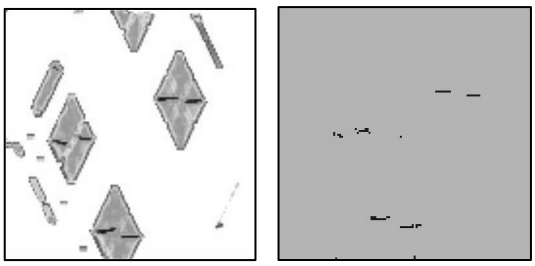
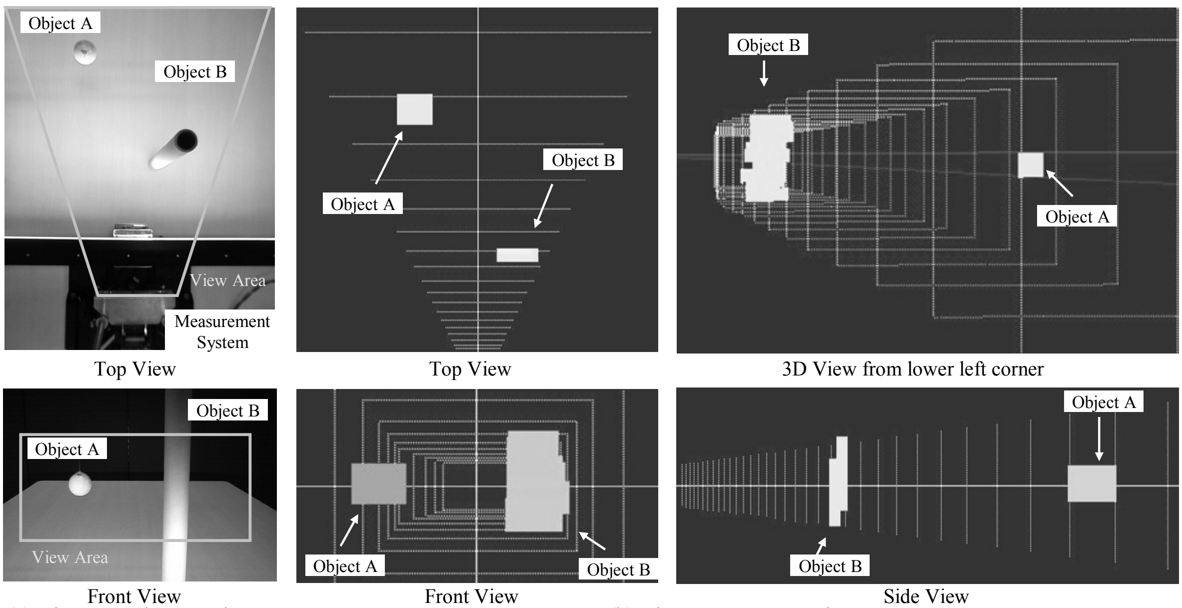


Fig. 1 Chip microphotograph



(a) Conventional output (Grayscale of the correlated value)
(b) High-speed output (addresses mapping)

Fig. 3 Correlation data output result



(a) View area photograph
(b) View area 3-D mapping

Fig. 4 Measurement result of detect 3-D position