A NEW IMAGE SENSOR WITH PROGRAMMABLE SPATIALLY VARIANT MULTIRESOLUTION READOUT CAPABILITY

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1. INTRODUCTION

For a variety of image processing tasks, such as biological vision modeling, stereo range finding, pattern recognition, target tracking, and transmission of compressed images, it is desirable to have image data available at varying resolutions to increase processing speed and efficiency. The user can then obtain a frame of data at the lowest resolution necessary for the task at hand and eliminate unnecessary processing steps.

We present a new image sensor with programmable multiresolution readout capability. The proposed image sensor can output data at varying resolutions. For instance, software intensive image pyramid reconstruction can be eliminated. Differing to our previously reported spatially variant sampling which sub-samples without filtering[1], in the multiresolution sensor, pixels are performed moving average and read out then, the new sensor does not suffer from aliasing effects. The multiresolution image sensor has a 64×64 pixel array that is programmable to read out the averaged values around the center pixels. The moving average is computed for differing block sizes (3x3, 5x5 or 7x7) that can be controlled locally. We can select the moving average block size for each center pixel.

2. MULTIRESOLUTION SENSOR

Multiresolution image sensor outputs data at varying resolutions, by placing signal processing circuitry on the imaging focal plane. There has been work related to multiresolution output[2]. Figure 1 shows Kemeny's method in case of 3×3 pixels block. In this method, there are a network of capacitors to store pixel values and a set of switches to the adjacent column to perform averaging on any square array of pixels. Pixel values in a block are read out to the capacitor and averaged. Since the block can not overlap to adjacent one, it outputs a single average value for a block.

Figure 2 shows our proposed method that enables moving average. In this method, we can set a averaging block to each pixel as the center of the block, and the block can overlap to the adjacent one. In order to implement this method, we designed a pixel circuit as shown in Figure 3. Pixel values of each pixel is stored and used multiple times to enable moving average by block overlapping. The integration time is controlled uniform for all pixels by the use of electronic shutter.

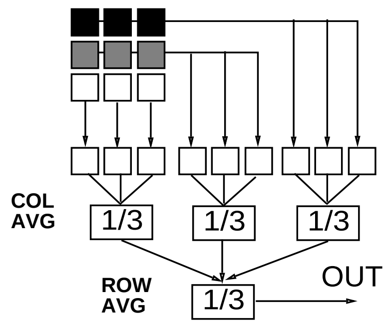


Figure 1: Kemeny's method.

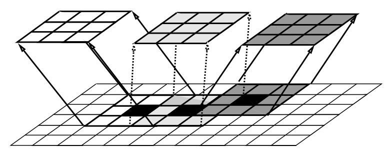


Figure 2: Moving average implemented in the proposed multiresolution sensor

3. DESIGN AND OPERATION

The pixel circuit shown in Figure 3 has PD, electronic shatter(ES) and two capacitors (C1 and Cp1). C1 is the one for sampling and holding of the pixel value and keeps it during 1 frame. Cp1 is the one used for

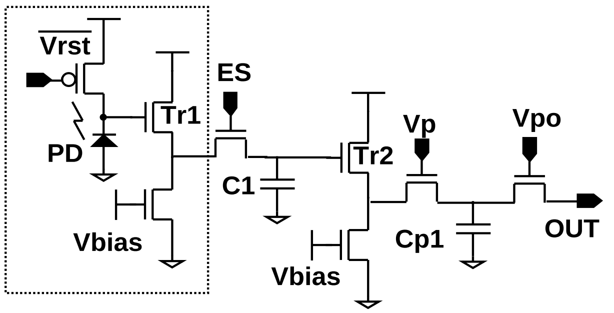


Figure 3: pixel circuit

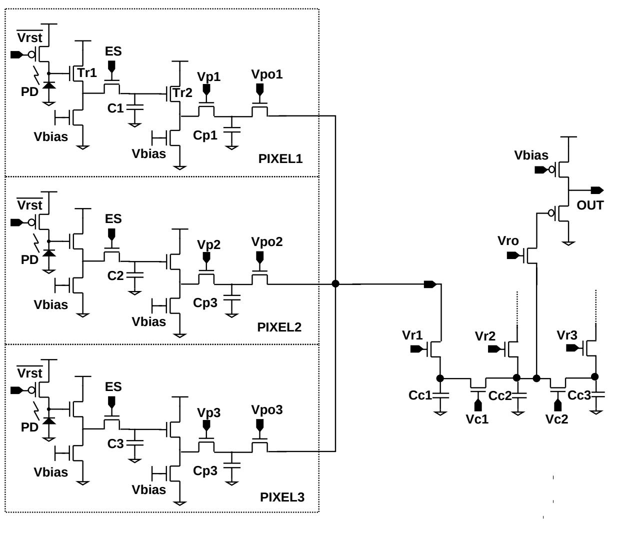


Figure 4: Smoothing process in 3x3 block.

the averaging of the pixel values. Capacitance of C1 is about 300fF, because pixel values have to be kept during 1 frame. A capacitance of Cp1 doesn't have to be so large, but is also about 300fF by the influence of the wiring capacitance. The circuit uses a passive switched capacitor network to average the pixels in a chosen size of block, which can then be read out by a set of shiftregisters. After switching off the ES, since a photo detector circuit (dotted line block in Figure 3) is independent to the computation circuit, the integration time of pixel value is not influenced by the averaging process.

Figure 4 shows smoothing process in 3x3 block. We use three capacitors (Cp1,Cc1,Cp3) for vertical averaging. When the pixel2 is the center pixel, Cp2 is not used and the pixel value is charged directly into Cc1. In PIXEL1 and PIXEL3, the values are charged into Cp1 and Cp3. Vertical averaging is finished by reading the pixel values and Cp1, Cp3, Cc1 are averaged. Three averaged pixel values kept in Cc1 to Cc3 are horizontally averaged by switching on Vc1 and Vc2. Then, we get the averaged value of the block.

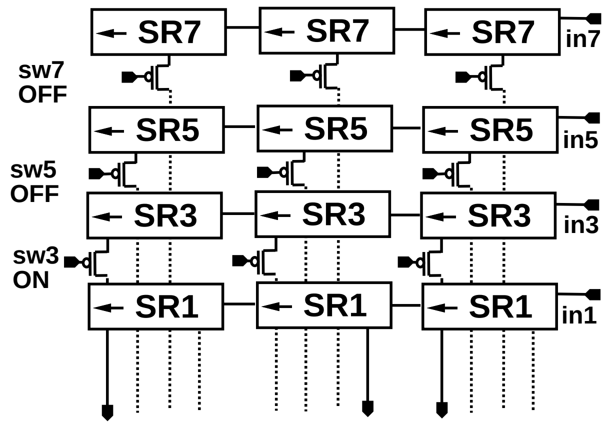


Figure 5: Determination of block size (3x3).

Figure 5 shows determination of block size in case of 3x3 pixels. We use four shiftregisters to select the block size. The size of the block is chosen by control signals sw3 to sw7, inputted from the outside. If sw3 is ON and sw5 and sw7 are OFF, signal from the SR3 is used for selecting the block size. SR1 is used to determine the center pixel address. The output signal from SR3 to SR7 are symmetrical with respect to SR1 as shown in Figure 6.

Figure 7 shows a circuitry of the horizontal shiftregister. The averaged three pixel values are stored in Cc1 to Cc3. Vc1 and Vc2 are switches for horizontal averaging. Vc1 to Vc3 are controlled by the SC (switching circuit) so that only the adjacent SC circuits within a block are activated. Vc3 is not switched on for 3x3 block averaging as shown in Figure 7. The value of C2, the center pixel, is output.

Figure 8 shows a block diagram of the prototype. There are a sensor array of 64 $\times$ 64 pixels and vertical and horizontal shiftregisters for block size selection and averaging pixel values. Both the shiftregisters determine the pixel address as a center of averaging block and choose the block size. The block size is controlled by sw, and locally changed arbitrarily within 3x3 to 7x7.

4. PROTOTYPE CHIP

Figure 9 shows a prototype chip of the proposed sensor. The chip is designed under 2-poly 2-metal CMOS

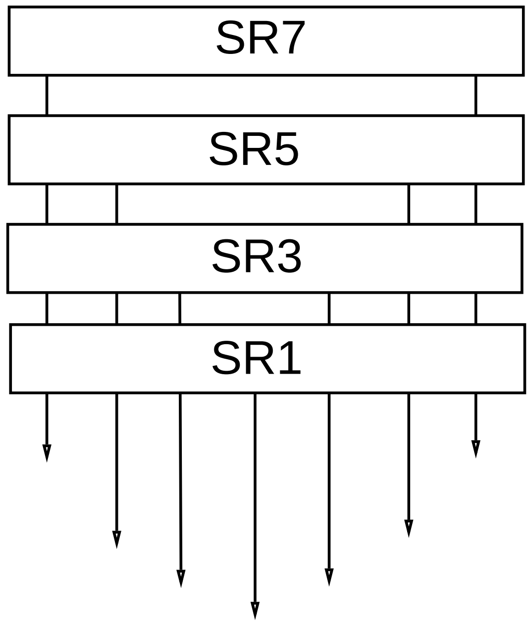


Figure 6: Layout of block selection signals.

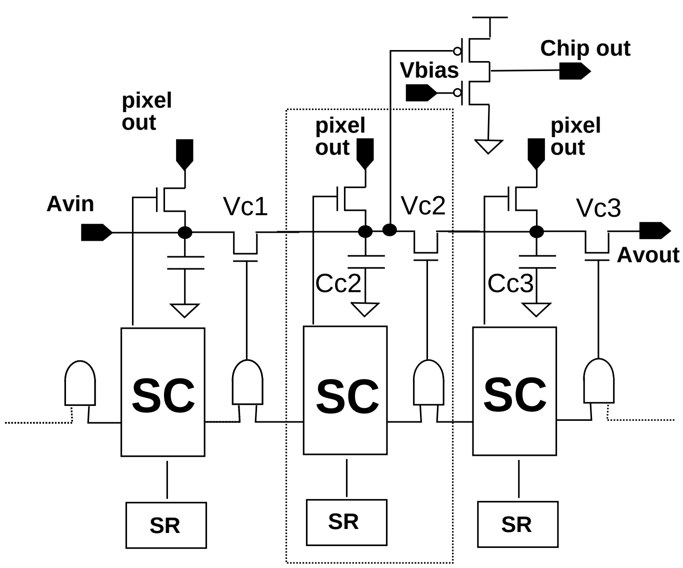


Figure 7: Horizontal shiftregister.

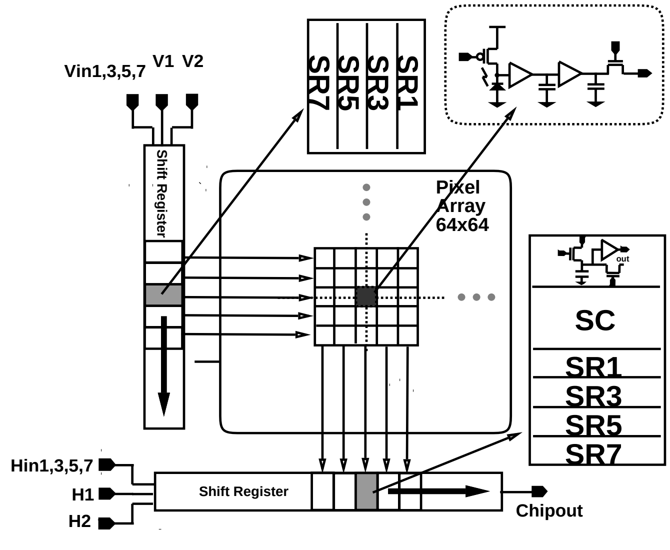


Figure 8: Block diagram of the prototype.

$0.8\mu m$ process rules. Number of pixels is 64×64 and an arrangement of each elements follows the block diagram shown in Figure 8. Table 1 shows the outline of the prototype.

Table 1: Performance of the prototype.

Number of pixels	64×64
Chip size $[mm^2]$	5.5×5.5
Pixel size $[\mu m^2]$	60×60
Number of Tr.	9 trs. / pixel
Fill factor [%]	14.5 %
Power dissipation[W]	0.25
Power supply[V]	5

Fig.10 shows images obtained by the prototype. Fig.10 (a) is a normal image of 64×64 pixels. Fig.10 (b),(c) and (d) are moving averaged images, the block sizes are 3×3, 5×5 and 7×7, respectively. Fig.11 shows images in which averaging block sizes are controlled in spatially varing way. Fig.11 (a) shows the normal output image obtained by the prototype. Fig.11 (b) shows the retina-like outputted image. In fig.11 (b), around the central area, image is outputted without smoothing, and in the peripheral area, spatially varying moving average is performed 3x3, 5x5, 7x7. The average block size is larger in the outer area.

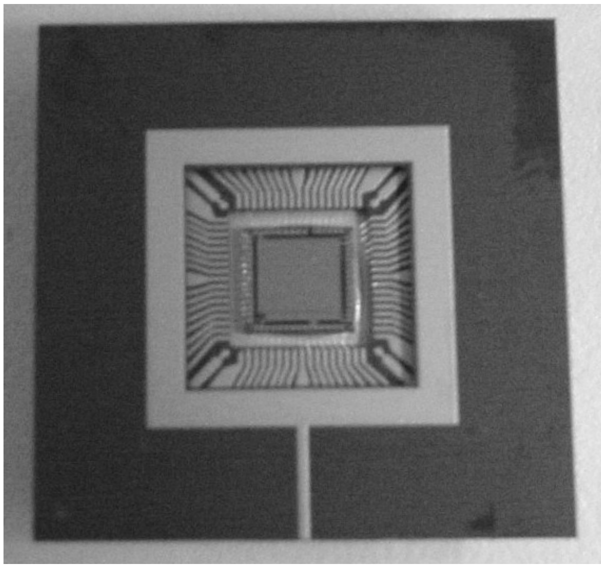
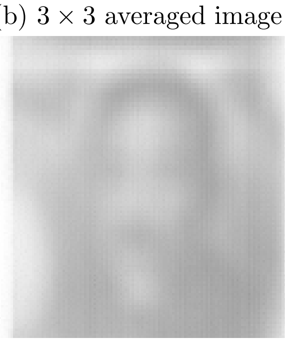


Figure 9: prototype chip

(a) Normal output

(b) 3×3 averaged image

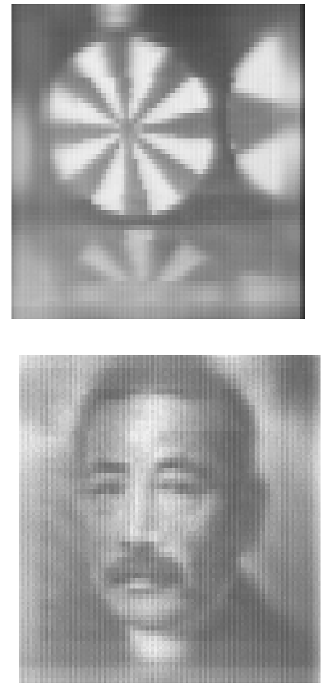
(c) 5×5 averaged image



(d) 7×7 averaged image

Figure 10: Image obtained by the prototype.

(a) Normal output



(b) Spatially variant MA output

Figure 11: Spatially variant moving average (MA) obtained by the prototype.

5. CONCLUSION

We propose a new computational image sensor with programmable spatially variant multiresolution readout capability. We described the principle of processing,designs of their circuits and experiments. The following functions are implemented and verified.

- The one of four block sizes for averaging is chosen and locally changed.
- The averaging blocks overlap, and moving average is computed.

6. REFERENCES

[1] Y.Ohtsuka, T.Hamamoto, K.Aizawa, “A New Iamge Sensor with Space Variant Sampling Control on a Focal Plane”, *IEICE Trans*, Vol.E83-D, No.7, pp.1331–1337,(2000)

[2] S. E. Kemeny, etc:“Multiresolution Image Sensor”, *IEEE Trans. on CS VT*, Vol.7, No.4, pp.575–583,(1997)