Motion Adaptive Image Sensor

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Abstract— We propose a motion adaptive sensor for image enhancement and wide dynamic range sensing. The motion adaptive sensor is able to control integration time pixel by pixel. The integration time is determined by saturation and temporal changes of incident light. It is expected to have high temporal resolution in the moving area, high SNR in the static area, and wide dynamic range. We have fabricated a prototype and show some results obtained by our experiments.

I. Introduction

Image sensors have many limitations. Among the limitations, limitation of temporal resolution is the most serious to imaging quality. Because of limited temporal resolution, motion blur and signal saturation are often observed.

In this paper, we present a motion adaptive sensor which solves motion blur and saturation by adaptive integration, in which integration time is variable pixel by pixel. The proposed sensor not only operates at high frequency but also detects motion and saturation. The motion adaptive sensor is able to control the integration time for each pixel, which results in no motion blur and no saturation. It is expected to have high temporal resolution in the moving area, high SNR and wide dynamic range in the static area.

II. Motion Adaptive Integration Time

In order to control integration time pixel by pixel, signal processing circuits are combined with the image sensor. Fig.1 shows processing scheme in each pixel of the proposed sensor[1]. It is based on detection of motion and saturation. Each pixel keeps integrating charge on photo diode (PD) and is not reset until it detects motion or saturation. As shown in Fig.1, photo diode stores $\int_{t-n\Delta}^{t} i\ dt$ $(= I_{PD})$, and the capacitance C_{st} keeps a delayed value of I_{PD}, $\int_{t-n\Delta}^{t-\Delta} i\ dt$ $(= I_{Cst})$. Minimum interval Δ is set very small because of high frequency operation.

I_t is calculated by the difference between I_{PD} and I_{Cst}. If the magnitude of the difference between I_t and I_{Cm} is larger than a threshold(th_m), the pixel is detected as moving. (I_{Cm} is the last I_t when the pixel was detected.) When I_{PD} exceeds a threshold(th_s), then the pixel is detected as saturated. If the pixel is detected as moving or saturated, I_{PD} and I_{Cst} are output.

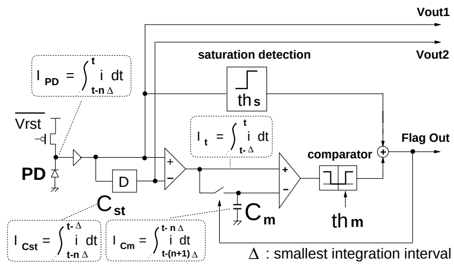


Fig. 1. Description of processing for each pixel

III. Design of Computational Elements of the Motion Adaptive Sensor

Fig.2 shows the block diagram of the motion adaptive sensor. We have designed the prototype by making use of column parallel architecture. This architecture separates transducer, memory and processing elements, and each column shares a processing element.

Two vertical shift registers for transducers and memories select the line in order. It has two horizontal shift registers, which are a normal and a smart shift register[2], and one of the two is selected. In case of the smart shift register, only the pixels detected as moving or saturated are selectively read out and non-detected pixels are skipped without reading. In order to reconstruct the pixel values, the flag signals are sequentially output by the bottom horizontal shift register at the rate higher than output rate of pixel value.

Prototype has been fabricated by using 1-poly 2-metal CMOS $1\mu m$ process. Table I shows the outline of the prototype. It has 32 × 32 pixels. Because of the column parallel architecture, the prototype keeps fill factor as high as the normal MOS imager and it has low power dissipation.

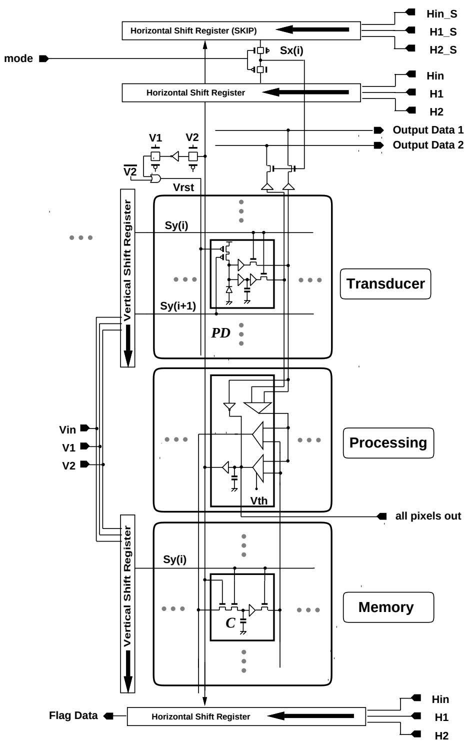


Fig. 2. Block diagram of the motion adaptive sensor

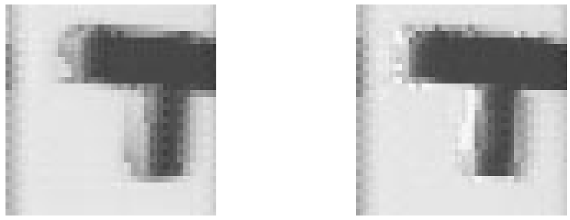
TABLE I
OUTLINE OF PROTOTYPE

number of pixels	32 × 32 pixels
die size	4.0 × 6.1 mm^2
pixel size	transducer : 85 × 85 μm^2 memory : 85 × 46 μm^2 processing : 85 × 191 μm^2
number of transistor	transducer : 17 trs. / pixel memory : 10 trs. / pixel processing : 64 trs. / column
fill factor	14 !s
power dissipation	150mW / chip (Vdd = 5V)
processing rate	$\geq$ 2 μs / row

IV. Experiments

Fig.3 shows images from the prototype when a figure of T is projected onto the focal plane. The figure of T is moving horizontally at high speed. When the motion detection is invalidated, motion blur is observed on the left side of T. When the motion detection is active, the motion blur is effectively removed.

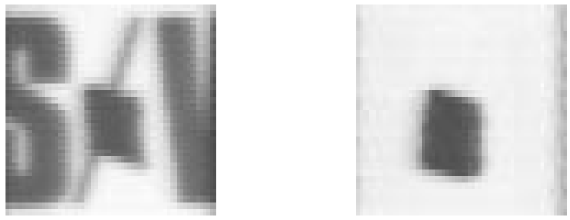
Fig.4 shows the images obtained by prototype when integration time is fixed or adapted. The scene of these images is partially very bright so that the sensor can not clearly acquire entire scene by a fixed integration time because of the limited dynamic range. On the other hand, it is verified that the proposed adaptive integration is able to capture both bright and dark region in the image. We have verified that the proposed sensor is applicable to higher rate imaging more than 1500 frames/second.



(a)without motion detection ($V_{th} = 0.0V$)

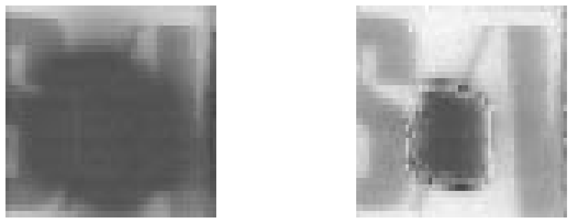
(b)with motion detection ($V_{th} = 2.0V$)

Fig. 3. Images obtained by the prototype. T is moving horizontally.



(a)imaging object used in experiments

(b)fixed integration time adjusted to center opening



(c)fixed integration time adjusted to the background

(d)proposed adaptive integration time

Fig. 4. Output images when integration time is fixed or adapted. (In the experiments of fig.(b)(c)(d), incident light through the center opening is very bright. Brighter area of image is in black due to inverse output.)

V. Conclusion

We present a motion adaptive sensor for image enhancement and wide dynamic range. We show the design of the prototype based on column prallel architecture, and some results of our experiments.

References

[1] T.Hamamoto, K.Aizawa and M.Hatori, "Motion adaptive image sensor for enhancement and wide dynamic range", *AFPAEC'96*, pp. 137–145, 1996.

[2] K.Aizawa, Y.Egi, T.Hamamoto, M.Hatori, M.Abe, H.Maruyama and H.Otake, "Computational image sensor for on sensor compression", *IEEE trans. on Electron Device*, Vol.44, No.10, pp.1724-1730, 1997.