ON SENSOR VIDEO COMPRESSION

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Abstract

In this paper, a novel image sensor on which video signal can be compressed is presented. Since video signal is compressed on an imager plane by making use of parallel nature of image signals and very fast analog processing, the amount of image data read out from the imager can be reduced with significantly small latency. The proposed sensor can be potentially applied to high pixel rate cameras such as those for very high speed imaging and very high resolution real time imaging which requires very high bandwidth; the very high bandwidth is the fundamental limitation for feasibility of those high pixel rate sensors.

Conditional replenishment is employed for the compression algorithm. Conditional replenishment is based on detection and coding of the moving areas, which are replenished from frame to frame. In each pixel, current pixel value is compared to that in the last replenished frame; the value and the address of the pixel is extracted and coded if the magnitude of the difference is greater than a threshold. Although conditional replenishment is rather simple, it can achieve 10% compression ratio without significant degradation.

Analog circuits have been designed both for processing in each pixel and for controlling entire data rate. A prototype of a VLSI chip has been fabricated and it is currently being examined. Some results of the examination are shown in this paper.

1 BACKGROUND AND MOTIVATION

Image acquisition requires transducing (detection) and read-out. In order to read out image signal which is inherently two dimensional, usually, image signal is firstly scanned into one dimensional signal and read out. When the pixel rate gets higher, it becomes more difficult for conventional image sensors to read out signals. The bandwidth to transfer data from sensor in the scanning-and-read-out process is a fundamental limitation for very high pixel rate imaging such as very high frame rate imaging or very high resolution imaging.

Image acquisition is also critical for real-time image processing. Real-time image processing system proceeds in three steps; transducing, read-out and processing. This sense-read-and-process paradigm does not make use of 2D nature of image signals. The high bandwidth required to transfer data from the sensor to the processor is a fundamental disadvantage of the paradigm because it leads to high latency. In addition to the disadvantage, the paradigm demands expensive, large computation units in order to perform real-time applications.

Tightly combining image acquisition and signal processing is an approach to overcoming the above difficulties. In this paper, we present a novel integration of sensing and compression. By integrating compression and sensing, the bandwidth required to transfer signals from sensor is significantly reduced. Thus, on-sensor-compression is especially needed for application uses such as high speed cameras and high resolution cameras.

In this paper, on-sensor-compression based on conditional replenishment algorithm is investigated. Conditional replenishment works independently pixel by pixel, so that it can exploit the parallel nature of the image signal. We designed an analog processing circuit for each pixel, and fabricated a prototype chip. Currently, the chip is being examined. Some results of the examination are shown in this paper.

Related works in terms of integration of signal processing and sensing are found in those areas of machine vision applications and neural network researches[1, 2, 3, 4]. By integrating processing and sensing, the parallel nature of the image signal can be exploited and the processing gets remarkably faster. In those works, for example, a silicon retina that is a device which computes spatial derivatives of an image and an analog network that calculate optical flow have been developed.

Notable differences between on- sensor-compression and conventional digital compression methods are:
1) On-sensor-compression reduces the pixel rate output from the sensor, while the digital compression methods does not.
2) Processing of on-sensor-compression is very fast by making use of parallel nature of image signal.

3) Processing of on-sensor-compression is so fast that the rate can be controlled in a single frame, while usual digital compression methods have to resort to buffer control to keep bit rate on an average.

2 ON-SENSOR-COMPRESSION BY USING CONDITIONAL REPLENISHMENT

We utilize conditional replenishment [5] for video compression algorithm on a imager. Conditional replenishment is based on detect and coding of the moving areas so that it makes use of temporal redundancy to compress video signals. As shown in Fig.1, current pixel values are compared to those in the last replenished frame; values and addresses of those pixels are extracted and coded where the magnitude of the difference is greater than a threshold. Although conditional replenishment is rather simple, it can achieve 10% compression ratio without significant degradation.

The detection algorithm of conditional replenishment is highly parallel so that the detection can be done in each pixel.

We have designed an analog processing circuit for each pixel. Each pixel detects motion and activates a flag signal when the difference between the current pixel values and the last reproduction values.

The entire sensor architecture is shown in Fig.2. Using horizontal and vertical shift registers, the pixels are scanned and only the activated pixels are selectively read out. Non-activated pixels are skipped without reading. The selection is controlled by using the flag signal.

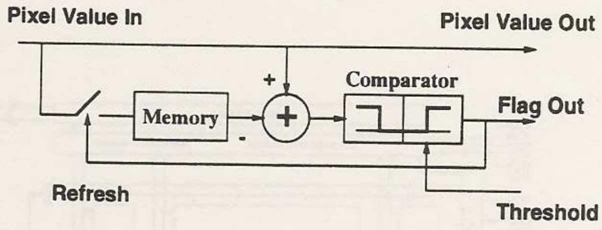

Figure 1: Description of coding algorithm in each pixel by conditional replenishment

3 ON-SENSOR-COMPRESSION CHIP

A prototype VLSI of the on-sensor-compression chip has been fabricated, which is shown in Fig.3. The chip has 32 pixels × 32 pixels and the size of the pixel is $170\mu m \times 170\mu m$ under $2\mu m$ CMOS process.

An image from the sensor is shown in Fig.4, when all of the pixel values are forced to be read out. Although some sensitivity variation in pixels is observed (because the process we utilized was not for analog VLSI fabrication), we can confirm the whole image can be read and shift registers work.

We have also fabricated a VLSI circuit of a single pixel to examine the behavior of the circuit in the pixel. One of the re-

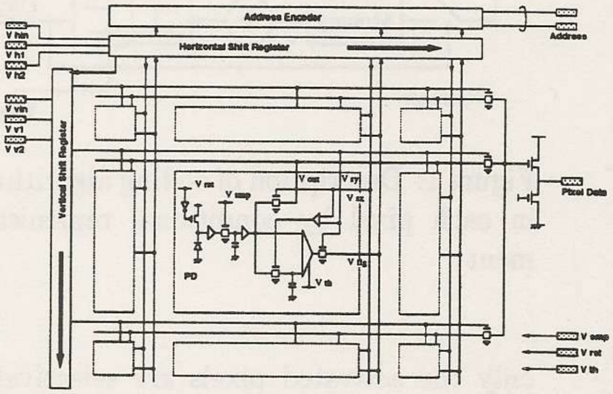

Figure 2: Description of the design of the sensor architecture

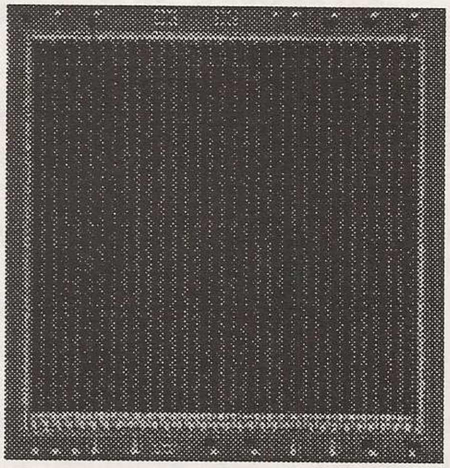

Figure 3: A prototype chip of the on-sensor-compression

sults is shown in Fig.5. In this examination, a LED driven by a sinusoidal wave is used. The sampling rate is set to 1ms. We can observe in Fig.5 that the flag signal is reasonably activated and the pixel circuit correctly works. Then, the compression sensor is applicable to high rate imaging of at least 1000 frames/s. The prototype chip is currently under further examination.

4 CONCLUSION

In this paper, a novel approach to video compression that integrates a video compression algorithm on a image sensor is proposed. We described the principle, the prototype sensor and some experimental results by the chip.

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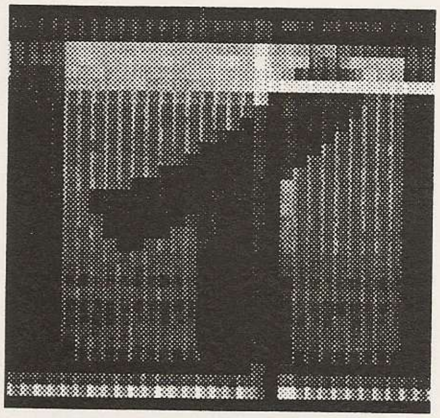

Figure 4: An image output from the compression sensor

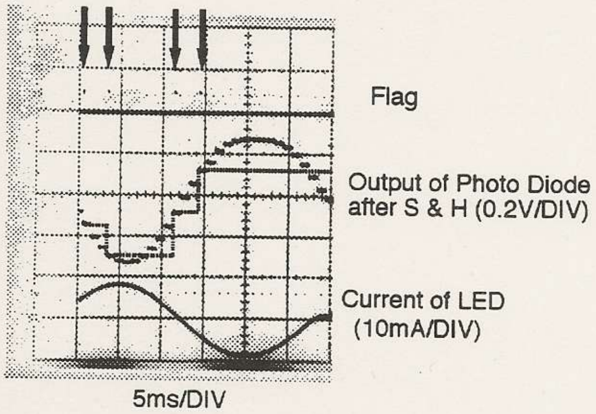

Figure 5: Behavior of the VLSI of a single pixel. Bottom: LED driving current, Middle: Sampled output of photo diode, Top: Activated flag signal (arrows are written to point the activated flags. Sampling rate (integration time) is 1ms. The dotted line in the middle is an estimated reconstruction in the replenished memory.