NOVEL AUTO-ADAPTATIVE INTEGRATION-TIME TECHNIQUE FOR CMOS IMAGE SENSOR

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Abstract:

In this paper, we present a novel technique developed in order to extend the dynamic range of a linear CMOS image sensor. This technique allows covering all the range of luminosities by auto-choosing the appropriate integration time. The proposed system is inspired form the human vision where we mimic the neural photoreceptor adaptation. The emulation results of the MATLAB model are shown to validate our approach.

Introduction:

The dynamic range limitation of the linear CMOS image sensors is still one of the most problematic issues in the field of imaging techniques. Several researches on this subject are pursued along the last years. In [1], authors propose to implement 4 analogue memories inside each pixel allowing thereby, acquiring images with four different integration times. The final image is then reconstructed by choosing the most suitable integration time per region. Otherwise, bio-inspired approach is developed in [2], this approach mimics the photoreceptors functionality of the human eye by shifting their response interval. In this work the integration time in the sensor array is locally adjusted using the previous frame. Also in [3,4] the authors propose to simultaneously capture and adaptatively compress luminosities using a tone mapping scheme calculated from the previous image. Moreover, the algorithm proposed in [5] aims to predict the optimum integration time of each pixel using two captures. Yet, [6] presents each pixel as a floating point, using the analog value of the luminosity and the number of the integration step restart during the frame capture a HDR image is reconstructed.

Proposed architecture:

In this paper, we present a novel technique developed in order to extend the dynamic range of a linear CMOS image sensor. The first intuitive idea for an integration-type sensor would be to extract several images with several integration times and reconstruct a final one based on these images. But since the readout of several successive frames is costly in time, motion in the scene will likely causes distortion in the final image because the successive frames memorized inside the matrix may change briefly in time. In addition, this approach is also costly in power, thus smarter idea is then so needed. What we propose in this paper is to distribute the sensor into macro-pixels of 2x2 pixels supposing that such small region (especially in sensors with high resolutions) receives relatively homogenous luminosities on its pixels (fig.1 extracted from à 256x256 pixels sensor).

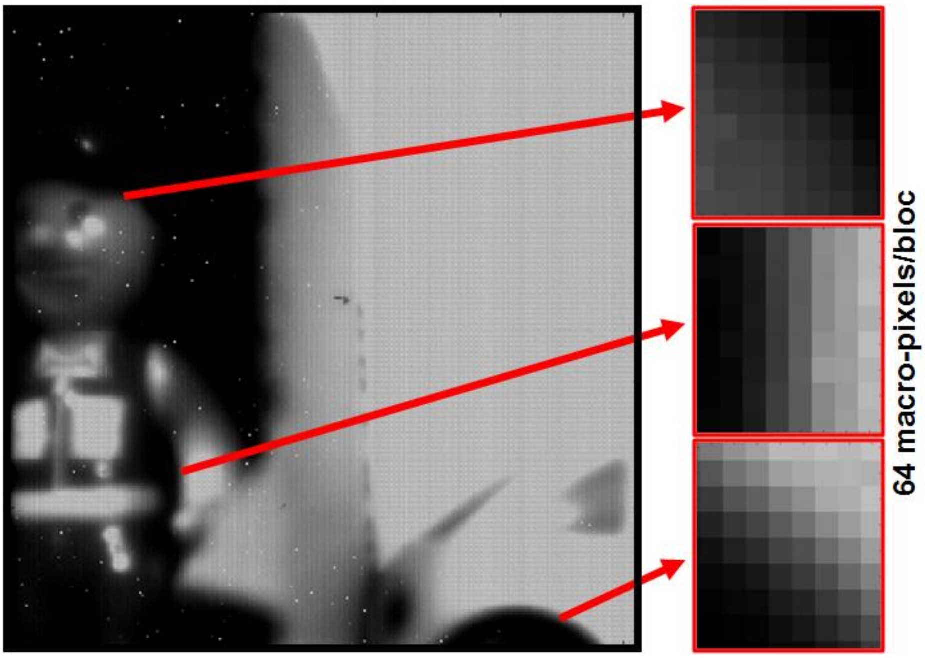

Figure 1: Illustration of the edges in the scene showing that on a macro-pixel of 2x2 pixels the luminosities are still relatively homogenous (no sharp contrast in the macropixel)

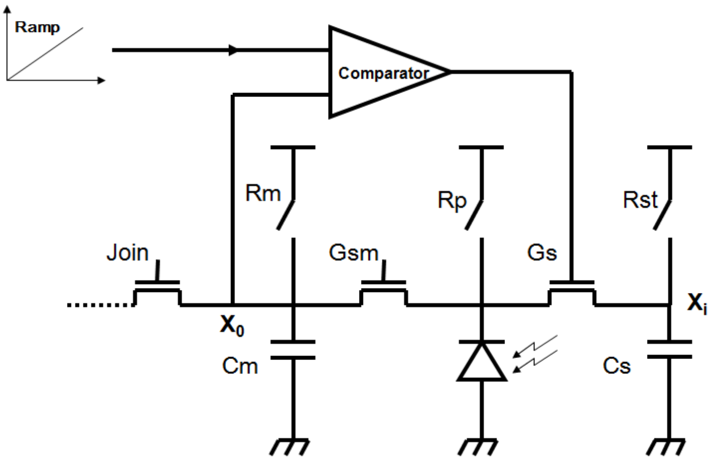

Figure 2: schematic of the proposed pixel

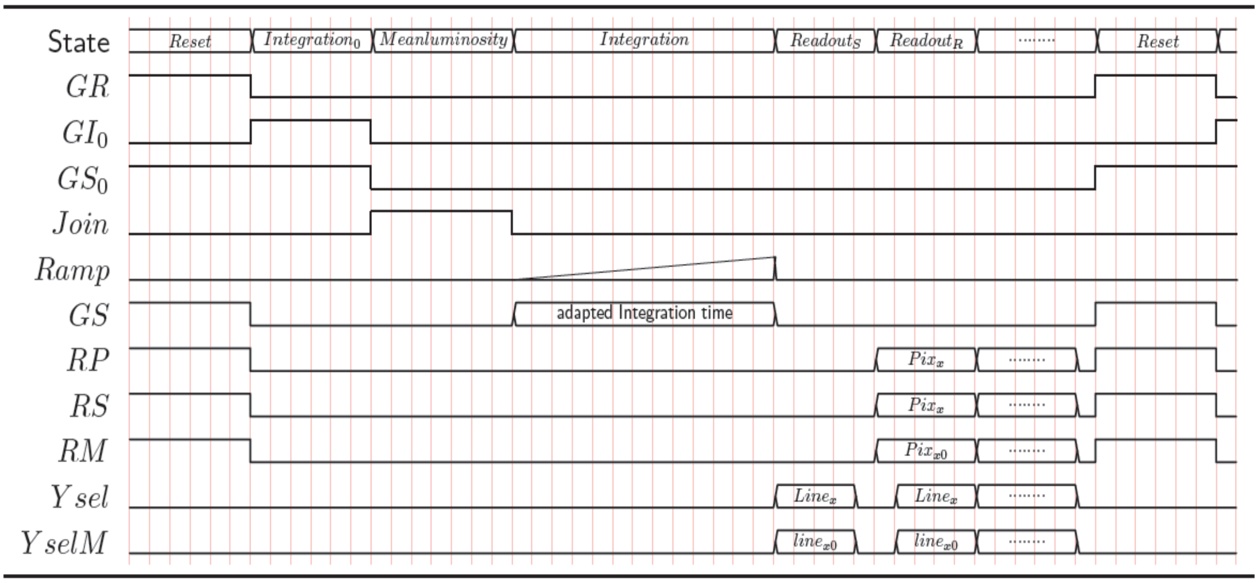

Figure 3: Timetable illustrating the proposed architecture functionality

Each macro-pixel provides at each frame, five output signals; the local luminosity of each pixel X_i (four signals) and their mean value X_0 (fifth signal) (fig.2). In this sensor, the acquisition is operated on two phases; firstly comes the mean value extraction. This mean value compared to an external ramp voltage signal permits to control the integration time of the bloc during the next phase. So, the correction of the integration time is locally applied to each macro-pixel, basing on the mean value of its proper luminosities (X_0). Note that the X_0 value is preserved to enable proper scaling of the readout X_i values during the correction operation. Moreover the X_0 value may be used in many image processing algorithms like local tone mapping (good contrast, no additional inexistent edges) (fig.4). MATLAB modeling of the technique proves its efficiency. Processing results are illustrated in fig.3. CMOS analog design is done using the technology CMOS 0.35µm of Austria MicroSystems. Schematics and simulation results of the designed comparator are also shown in the figures 5, 6 &7.

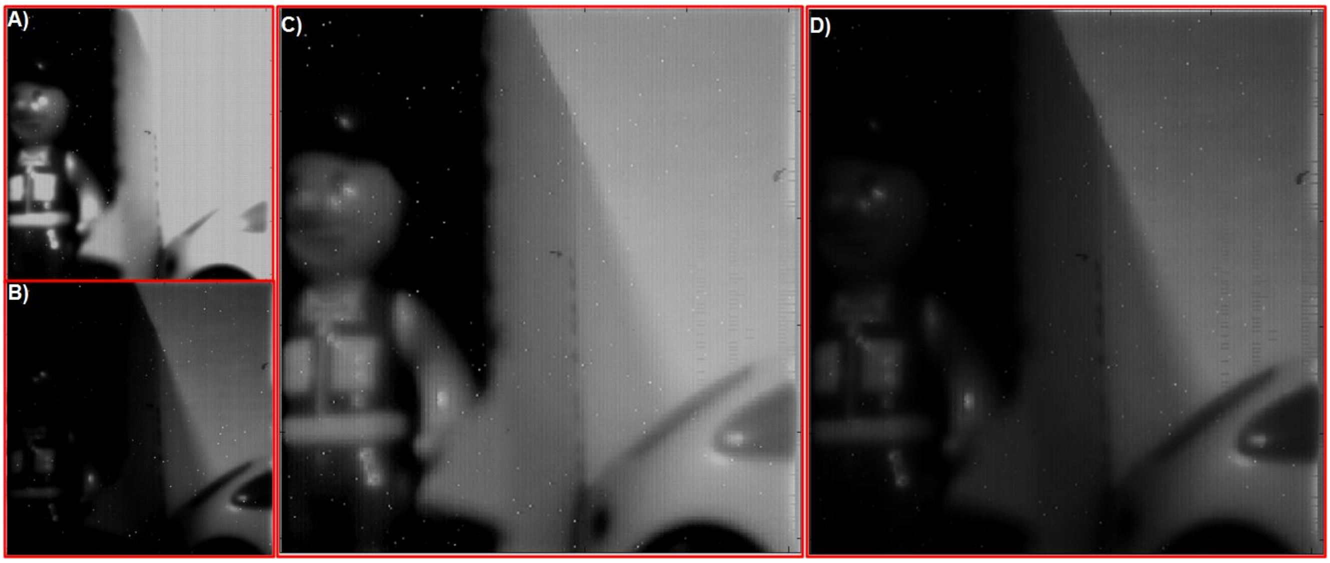

Figure 4: Scene: A) captured with a long integration time (white saturation), B) captured with a short integration time (black saturation), C) result of local adaptation processing, D) corrected resulting image

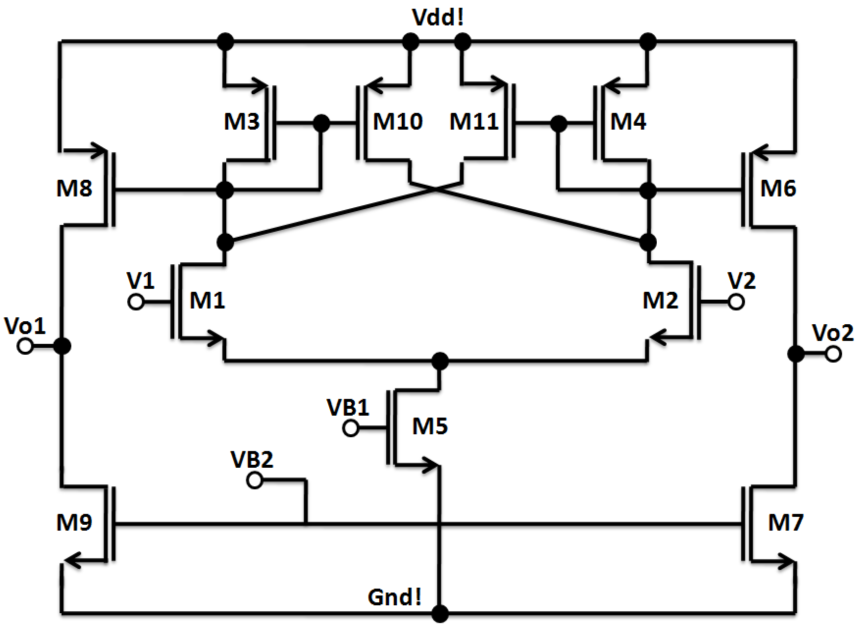

Figure 5: Double based OTA comparator schematic

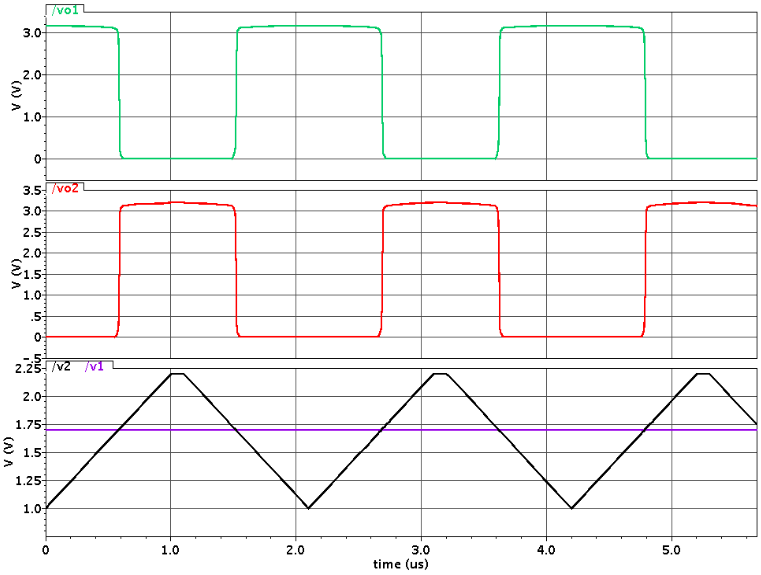

Figure 6: Transient simulation of the comparator where V1 and V2 are the two inputs VO1 and VO2 the outputs

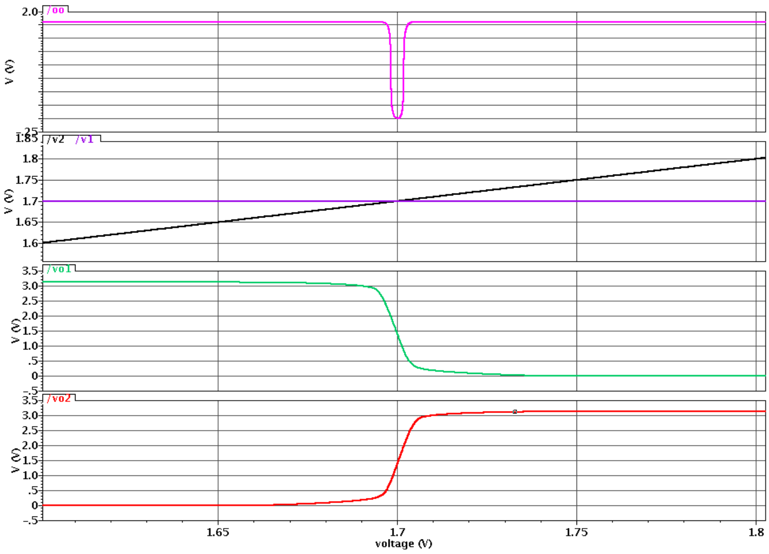

Figure 7: DC simulation of the comparator

Conclusion

In this paper we present a new auto-adaptative CMOS image sensor architecture. After the introduction of the problematic issue, a study of the state of the art is presented. The architecture of the proposed technique is detailed with MATLAB emulation model that proves the efficiency of the proposed technique. A prototype chip is already designed and is actually in fabrication process. The experimental results will be published in a new following paper.

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