Title: Wide Dynamic Range 2D Motion Detection Circuits (TSMC35_P2)

Project Description:
This project is a design of wide dynamic-range motion detector in two-dimensional space. Most existing motion detection chips today are to detect object moving-direction in one-dimensional space. Our preliminary circuit simulation results [1] [2] show that it is possible for our design to detect object moving-speed in addition to object moving-direction in two-dimensional space. This research includes three tasks as follows.

Task 1: Design of small footprint photo detector arrays
To realize the full function of the visual chip, we first need to characterize the opto-electronic properties of the photo detector in terms of sensitivity, dynamic range, and pixel size. We will also test the multi-spectral response of the photoreceptors for wavelength ranging from 100nm to 1100nm.

There are two types of CMOS photoreceptors: photodiodes and phototransistors. Because of the amplification of the transistor, phototransistors can achieve about 100 times photocurrent as that of a photodiode taking same area. Since phototransistors expand the sensible dynamic range of the visual chip to non-bright or dark area, they will be the main concentration of study in this project. With the test results and analysis of these CMOS photoreceptors, we can go on with implementation of the visual chip with enhanced functions in the next step.

Task 2: Design of low-power high-speed readout Circuits with wide dynamic range
Wide dynamic range of the input light density (>5 decades) is hard to deal with because of the mismatch and noise in silicon chips. Existing methods to increase the dynamic ranges readout circuits are optical shift, averaging, and range compression. Optical shift is to adjust optical aperture, which needs manual adjustment or additional mechanic structures with feedback circuitry. The dynamic range at one time is still unexpanded. In addition, more power is consumed and the size of the system is increased with mechanic extension. There are two averaging methods: subtraction from spatial average and division by spatial average (normalization). They both need manual adjustment or additional feedback circuitry. The dynamic range at one time is still unexpanded. Furthermore, averaging process introduces significant noises. Range compression is the other method to extend dynamic range of the read out circuits. This method is responsive to low luminance objects and high luminance objects at the same time. However, non-linearity reduces the sensitivity greatly. We propose a mirror duplication method to increase the dynamic range.

Task 3: Design of wide dynamic range 2D motion detector
Based on the result of task 2, we can design a two-dimensional motion detector with speed and direction calculation. Previous work [3] [4] [5] [6] [7] [8] on motion detection offers a variety of low-power, single-chip solutions to implement the biological insect models on silicon. Most visual chips detect motion by tracking the disappearance of an edge and its subsequent reappearing at neighboring pixel, using an edge detector. One of the major issues in the edge detector design is its robusticity in handling the background luminance change, the wide dynamic ranges of the input light density and the
speed of moving objects. For example, some designs require manual adjustment of the threshold voltage when environment luminance or input signal density changes, some designs tend to misinterpret periodical background flashing as motion, and some designs lose timing accuracy in edge detection, so they are not good for speed testing. In this research, a robust edge detector with spatial adaptation and temporal adaptation is designed; it is insensitive to background luminance variation and input density variation. The background luminance variation includes both background fluctuation (slow changing of background light density) and background flickering (fast flashing of the background light density). In addition, this design is responsive to moving object with wide speed range and it has fast transient response for speed calculation. Another major issue of motion detection chip is that the complexity of biological models usually requires large size capacitors and resistors, which limit the number of pixels that can be integrated on a reasonable size chip. In this work, we utilize the basic principles of biological models and balance it with the advantages of silicon processes, i.e. high-speed processing and compact size. The resulted edge detector will have relatively smaller size capacitors and resistors feasible for high-density integration.

**Estimated Project Size and Simulation Plans:**

We are planning to fabricate three minimum size chips in TSMC35_P2_NEW process (7mm²) for the three tasks. We are working on the layout of the chip for task 1 and will be ready for fabrication on December 3rd 2001 run, if granted the fund for fabrication from MOSIS. We are using Cadence/Hpsice to simulate the circuits.

**Test and Characterization Plans:**

The chip will be tested in Analog and Mixed-signal IC Design Lab at UT Dallas. Source measurement units to measure the photocurrent are available in the lab. Light source and luminance measurement units will be purchased. For task 1, the test of the first chip will focus on the sensitivity, dynamic range, dark current, and linearity of these photodiodes and phototransistors. Scaling effects of the photo detectors will also be analyzed. For task 2, the focus is the dynamic range of readout circuits. For task 3, we will test the motion detection function extensively for different environments and object moving-speed.

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