ABSTRACT

Digital vision sensors have been widely applied in various areas including consumer electronics, machine vision, security surveillance and so on. In the early days of digital cameras, charge-coupled-device (CCD) was the dominant technology because of its superior imaging quality. In recent years, with the advancement of complementary-metal-oxide-semiconductor (CMOS) technology, CMOS image sensors have prevailed and show their advantages of the higher integration, lower power consumption, more random accessibility and lower fabrication cost. The design of commercial visual sensor only focuses on the improvement of imaging quality by increasing the spatial resolution with smaller pixel size. When these sensors without on-chip computation capability are applied in the real visual system, they produce massive amounts of raw image data with a huge redundancies. Actually, in order to extract the image features of interest, such redundant raw data has to be transmitted and further processed by the entire post processing system, which inevitablely wastes tremendous hardware resources and causes significant power overheads. Moreover, this issue becomes even worse in the sensor network application. Therefore, there is a growing demand on the smart image sensor that can on-chip perform the image processing functions so that vision sensors can directly export the valuable image features.

In the visual processing application, motion feature is commonly used to identify the moving objects from the stationary background. Once the regions with motions are extracted, more advanced processing like image compression, object segmentation and even pattern recognition can be easily achieved on the input images. The fundamental principle of the motion detection is to monitor the light intensity changes along with time on a single pixel. Since light intensity can be transformed into electrical signals in the form of current, charges or voltages. By detecting the temporal variations on these electrical signals with the dedicated circuits, motion

detection function can be implemented on the image sensor. Various hardware implemented motion feature extraction image sensors have been reported recently. Existing motion detection image sensors can be classified into two main categories so called "integration mode" and "continuous mode". In the first mode, an analog intensity image is acquired by integrating incident light within a certain period. A comparison on two temporal consecutive frames can realize the motion detection function. However, due to the long integration period, this algorithm suffers from the serious aliasing effect with the low sensitivity to fast motions. In the "continuous mode", incident light brightness is directly converted into analog current or voltage without an integration procedure. By applying a continuous differentiation on these signals, motion features can be detected in a more efficient way. In order to report the motion activities in real time, researchers innovatively develop an asynchronous address-event-representation (AER) strategy export those motion events to the post processors. Unfortunately, because of the asynchronous nature, address event based processing visual system is extremely complex with a strong sensitivity to the random noise in the scenario.

The aim of this work is to design a smart CMOS image sensor that can extract and process the motion features on the same chip so as to simplify the entire visual system with less computation burden. We have made significant progresses toward this ultimate goal by developing several motion detection image sensors. The first image sensor was designed based on the temporal difference algorithm with an on-chip moving object localization function. In fact, this vision sensor is a compact visual system that integrates motion detection and object localization functions on the same chip. In order to maximize the photon sensitivity in every pixel, we developed a feature-extraction image sensor based on the emerging 3D integration technology. It can extract either motion feature or contour feature in real time. In this thesis, we also report an event-clustering image sensor for kinetic object tracking applications. This sensor continuously detects motion events and parallel processes them to export the "event-flow" features, which have shown the satisfactory performance on different object tracking algorithms.