CHAPTER 5

CRISP EDGE DETECTION USING GRATING LIGHT VALVE

5.1 INTRODUCTION

Recent advances in MEMS technology have made it possible to detect high dynamic range images which have better quality than the other bulk devices. A monochromatic image can be easily edge detected by the Grating Light Valve with its associated tools. In this section GLV is used to detect the edge of an object with noise, shadows corners, texture or other discontinuities in the background. The gradient output of the difference between two intensities is applied to the GLV pixel which results in a sharp edge location due to its very small size.

5.2 SCANNED GLV ARCHITECTURE

In the Scanned GLV Architecture (SGA), a linear array of GLV pixels is used to project a single column of image data. This column is optically scanned at a high rate across a projection screen. As the scan moves horizontally, GLV pixels change states to represent successive columns of video data, forming one complete image per scan. One of the most noticeable features of such display is that there is no visible pixelisation, even upon close inspection. The high inherent switching speed of GLV devices makes a scanned linear architecture, and its many benefits, possible. For example, to create a 1,920 × 1,080-pixel image with a 100 Hz refresh rate, each GLV pixel must change state 192,000 times per second. Thus, each pixel displays video data for 5.2 microseconds, quickly changes state, displays video data for another 5.2 microseconds, and so on. The Scanned GLV Architecture gives Silicon Light Machines an enormous advantage in terms of modulator cost. To create a 1,920 ×1,080-pixel image using Scanned GLV architecture, for example, one need to manufacture, interconnect, and address only a single linear array of 1,080 pixels; other spatial light modulator technologies would have to manufacture (with acceptable yields), interconnect, and address more than 2 million pixels. In addition to cost, there are a large number of other advantages that accrue to the Scanned GLV Architecture when compared to current and emerging technologies. The horizontal scan of the SGA architecture allows dynamic reformatting of the aspect ratio of the system. In the SGA architecture, each pixel writes one row of data for each screen refresh. In a scanned point system (a CRT, point-addressed light valve or a scanned laser system), a single channel must modulate an entire frame's worth of data every refresh. For a high-resolution system, this implies channel bandwidths three orders of magnitude higher than for the SGA system. The Scanned Linear GLV Architecture was introduced previously by David T. Amm et al (1998). A more complete description of the linear GLV array module and its associated electronic drivers was given by David T. Amm (1999). The linear GLV array's 1,088 pixels are at a pitch of 25.5 µm, thus giving a total active area of 25µm by 27.7mm. The linear GLV array is surrounded by four custom driver chips (each with 272 output stages) and assembled into a multi-chip module. The primary function of the driver chips is to provide the digital-to-analog conversion needed for analog gray scale control and to provide a significant degree of multiplexing so that the module pin count is significantly reduced.

5.3 EDGE DETECTION

Edge detection has an important role in image processing. Detecting the edges of an image or an object is one of the toughest tasks in image processing. Edge detection is the most common approach for detecting meaningful discontinuities in gray level (Rafael C. Gonzalez and Richard E. Woods, 2002). In this work, we consider an edge as a set of connected pixels that lie on the boundary between two regions. Detecting the edge requires ability to measure gray level transition effectively. Unfortunately, imperfections in image acquisition system yield blurred edges and make the task of edge detection, more complicated. Normally, blurred edges are thick whereas sharp edges are thin. For locating the edge points, the transition in gray level associated with that point has to be significantly stronger than the background at that point. Threshold method is used to determine whether a value is significant or not. This method guaranteed success in finding edges in an image to a greater extent. Mainly gradient and zero crossing based methods are used to find the edge location. In the detection processing, the display takes an important role to deliver the edges with sharpness. The sharpness in the edge boundaries can be improved by reducing the pixel size of the display device. In GLV the size of the pixel is 25 micrometer which delivers the output with high sharpness.

The edge detection mechanism is mainly based on the addressable, dynamic diffraction of Grating Light Valve which provides high-resolution images. Contrast ratio, fill ratio and optical efficiency are important criteria for distinguishing among various display technologies. High contrast ratio provides crisper image. A GLV system built using inexpensive optics exhibits a contrast ratio better than 200-to-1. Fill ratio is better than LCDs (Bloom 1997). High efficiency diffraction grating micro-structure is obtained by optimizing the parameters like ribbon width, ribbon gap, reflectivity of the top surface and grating depth. The GLV acts as a mirror to incident optical signals or as a precise angle deflector, depending on the positioning of the GLV ribbons. It includes electronic, mechanical, and optical components in a sophisticated configuration. This part of the thesis explains a novel architecture which meets demanding performance requirements for image enhancement, widely employed in medical imaging, computer vision, production quality control, etc. However, the definition of meaningful region is strictly dependent from the applicative context. The detector is comprised of a linear transducer, differentiator and a micro-optical square-well diffraction grating display, all assembled in a hermetic butterfly package.

5.4 DESIGN ASPECTS

Contour-based approaches try to generate closed boundary images. Parent and Zucker (1989); Montanari (1971); Williams and Jacobs (1995) explained some methods based on a preliminary step of edge detection and a process of connecting edges together in order to get extended contours.

The edge detection step is usually devoted to localize abrupt brightness transition between adjacent image points applying some gradient operator. Nevertheless, the subsequent process of linking edges together for building closed boundaries is a very difficult task. The edge detector uses a discriminating threshold whose value could be derived, for example, by the image histogram or calculated with other techniques. If this value is too low many random edges will be detected, on the contrary some true edges will be missed.

An ideal sinusoidal image has an intensity $F\left[x_a(i,j)\right]$, at absolute coordinates $\left[x_a(i,j)\right]$, where (i, j) is the relative pixel location in the subset, which is defined as follows:

$$F\left[x_a(i,j)\right] = \frac{225}{2}\left[1+\sin\left(\pi i/\lambda\right)\sin\left(\pi j/\lambda\right)\right] \tag{5.1}$$

where "λ" is the period of sinusoid, and the index α has the range 1,2.

The intensity of each pixel will therefore range from 0 (e.g., black) to 255 (e.g., white), which corresponds to a digital image with 8-bit gray level that would typically be used in the digital image compression technique. Evaluation of the individual values indicated that they are not always unique at integer and sub-pixel location. The image pixel intensity is correlated against the nearby pixel intensity by finding the intensity gradient. Intensity gradients can be calculated directly from the intensity values of adjacent pixels using bilinear interpolation scheme, which is formulated as

$$G\left[x_a(i,j)\right] = a_{00} + \left(a_{10} - a_{00}\right)\Delta x_1 + \left(a_{01} - a_{00}\right)\Delta x_2 + \left(a_{11} + a_{00} - a_{01} - a_{10}\right)\Delta x_1 \Delta x_2 \tag{5.2}$$

where a_{00} is the intensity of pixel(i, j), a_{10} is the intensity of pixel(i+1, j), a_{01} is the intensity of pixel(i,j+1), a_{11} is the intensity of pixel(i+1, j+1), and $\Delta x_1$and Δx_2 are the relative distances of the point from the pixel(i, j). Only four coefficients are required to calculate the sub-pixel intensities in the bilinear interpolation scheme. The bilinear interpolation scheme has been very popular because it is a computationally efficient scheme with reasonable accuracy for reconstructing images. The gradient image intensity of each region can be approximated by the mean value,

$$\mu(\Delta I) = \frac{1}{\left\| R_K^k \right\|} \sum_{G[xa(i,j)] \in R_K^k} G[x_a(i,j)] \tag{5.3}$$

where $R_K = \{R_K^1, R_K^2, \ldots R_K^k\}$ is the K partition of the input image and $\mu(\Delta I)$ is the mean value of the intensity gradient. This mean value constitutes a piecewise constant approximation of the region that decides the threshold value to find the edges of an image. Even the pixel dimensions are scalable, a typical 25 µm single pixel having six ribbons, each about 4.15 µm wide, and 100 µm long yields crisp edges of an image. The contour intensity gradient C_i is calculated using the following equation.

$$C_i = \begin{cases} 1, \; when \, G[x_a(i,j)] \geq \mu(\Delta I) \\ 0, \; otherwise \end{cases} \tag{5.4}$$

The contour intensity gradients C_i are applied to the transducer and the resultant electrical control signals are applied to the Grating Light Valve which displays the negative of the edge deducted signal. The camera man picture is taken for the analysis. The region of the boundary edges of a camera man picture displays through the LCD display is shown in Figure 5.1 and at the same time the region of the boundary edges of a camera man picture displays through the GLV display is shown in Figure 5.2. In Figure 5.2 the clarity of the edge detected image is improved. The edges of the shadow corners and discontinuities in the background of the picture with noises are crisply displayed by GLV pixel.

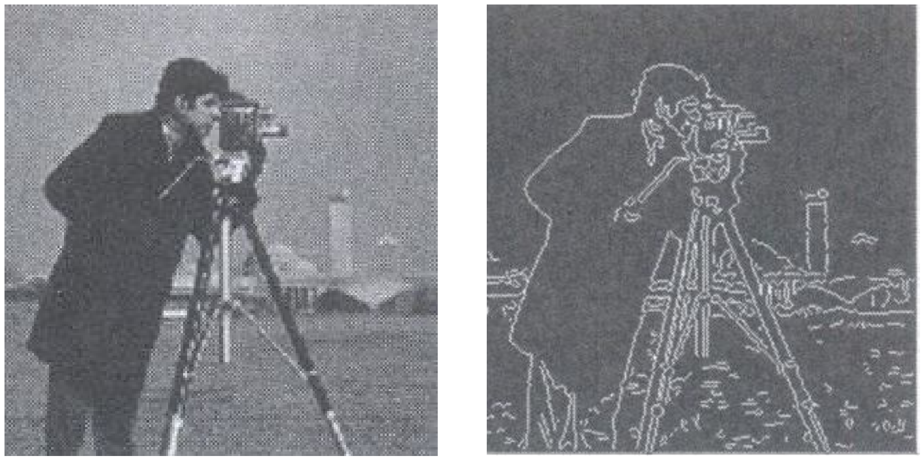

Figure 5.1 Edge detected image displayed in a LCD display

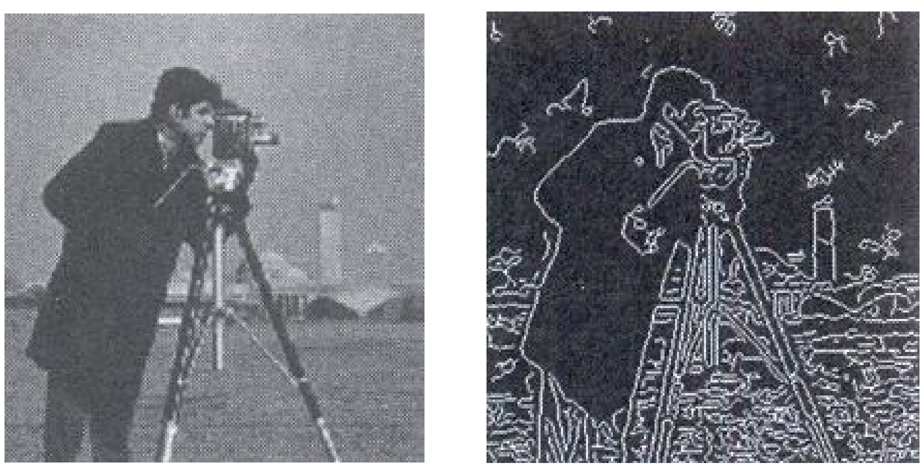

Figure 5.2 Edge detected image displayed in a GLV display