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Angle Position Detection Using a Novel Double Hollow Four Quadrant Orientation Detector for Application to Pattern Recognition

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The contrast edge position of an object and its orientation with respect to the horizontal line can be measured from the active hollow FOur QUadrant Orientation Detector (FOQUOD). Based on this device, a double FOQUOD device which can extract the angle position is proposed for the first time and has been fabricated successfully. The accuracy of extracting the angle positions of a random feature is beyond 55%.

1.INTRODUCTION

In recent years, many research groups have devoted their effort to the development of more intelligent electronic circuits in the area of pattern recognition[3-11]. It is believed that simulating the function of biological visual system is probably the correct way because this recognition machine has survived hundred million years evolution. Fundamentally, the first three features extracted from an object image in the brain are edge position, orientation and the angle position (possibly the magnitude of angle)[1]. To date, many algorithms have been developed to extract these three information in the field of image processing[2], however, it needs routine computations of the brightness level of each pixel and the processing time is proportional to the number of pixels.

Mead[3] who pioneered this area by constructing a silicon retina which could simulate the response of human retina. The first analog two-dimensional optical-flow chip made by Tanner and Mead[8] even can extract a single motion vector for the global two-dimensional optical flow. Recently, a functional two-dimensional silicon retina made by Delbruck[9] that uses unidirectional delay lines as tuned filters for moving edges computes a complete set of local direction-selective outputs. Other groups[10-11] have developed various algorithms to detect the motion velocity of the image using analog very large scaled integrated circuit.

A simpler way to fabricate the edge detector by means of the hydrogenated amorphous silicon (a-Si:H) technology was proposed by Sah and Lee[5]. Recently, our laboratory had implemented the hydrogenated amorphous silicon active hollow FOur QUadrant Orientation Detector (active hollow FOQUOD) which can extract the position and orientation of a contrast edge for application to neural network image sensor[7]. Although the active hollow FOQUOD can extract the edge position and orientation, it also needs a sophisticated software to find a angle position. It is believed that to find the angle positions of an motion image is another way to extract the motion vector. In this paper, we propose to solve this problem by developing a double FOQUOD device to extract the angle position, and the performances of this double FOQUOD are discussed.

2.EXPERIMENTAL

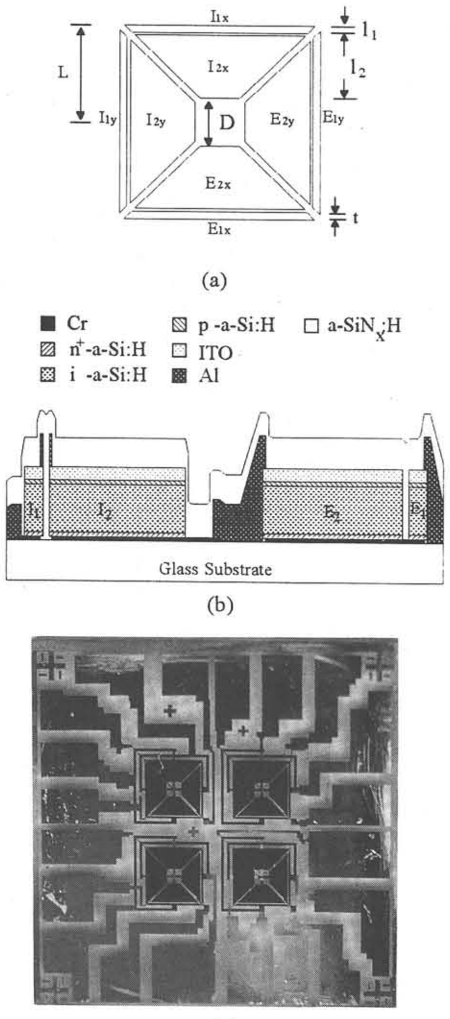
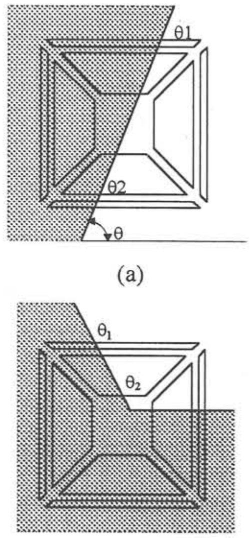


Fig. 1 (a) The top electrode geometry of an angle position d tector. It contains two hollow FOQUOD packed in a conce tric fashion, the outer and inner hollow FOQUODs are call F1 and F2, respectively. (b) Schematic diagram of the cros section view of the angle position detector. (c) The photogr phy of angle position detector. There are four fully same d tector on the glass substrate.



(a)

(b)

Fig. 2 (a) A contrast edge or (b) an angle lies across the detector. Two orientations θ_1 and θ_2 of the contrast edge with respect to the horizontal line are measured by F1 and F2, respectively. If θ_1 is equal to θ_2 ,the image is considered to be a contrast edge; otherwise the image is considered to be an angle.

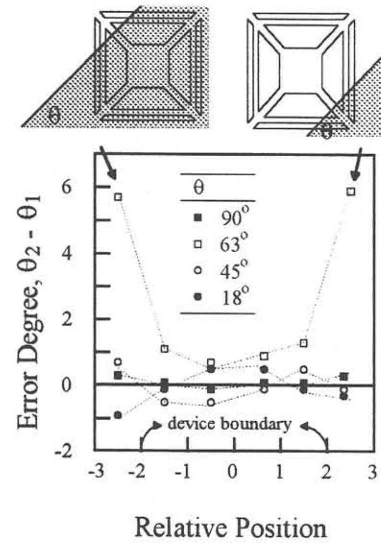


Fig. 3 The measurement results of error signal θ_2 - θ_1 when contrast edge with different angle θ with respect to the hor zontal line, i. e., 0°, 18°, 45°, 63° and 90°, respectively, mov across the device. The abscissa represents the intersecti position of the edge and the horizontal line passing throu the center of the FOQUOD.

The a-Si:H angle position detector is composed of two hollow FOQUODs packed in a concentric fashion and each FOQUOD consists of four p-i-n solar cells. The top electrode geometry of this detector is shown in Fig. 1 (a), the outer and inner hollow FOQUODs are called F1 and F2, respectively. The outer half side length of this device is 2 mm. The side length of inner hollow square (D) is 1 mm. The height of the solar cells of F1 (l_1) and F2 (l_2) are 0.15 and 1.3 mm, respectively, and the isolation gap (t) between each neighbor solar cells is 0.05 mm. The cross-section view and photograph of the angle position is shown schematically in Figs. 1(b) and (c), respectively. There are four fully same angle position detectors on the same glass substrate. At first the corning 7059 substrate was coated with a thermally evaporated 100 nm Cr layer as the bottom contact. Then the a-Si:H n-i-p layers were deposited by plasma enchanced chemical vapor deposition (PECVD) of SiH_4 gas in a single run at a temperature of 250 °C. The thickness and doping of n, i, and p layers were 30 nm with 7200 ppm PH_3, 500 nm undoped, and 18 nm with 4500 ppm B_2H_6, respectively. Third, a 150 nm indium tin oxide (ITO) was deposited as the top contact. After patterning the shape of double FOQUOD, a 500 nm thick Al was thermally evaporated on the top of ITO as the first interconnection layer. Then the sample was sent to the PECVD chamber again to deposit a 1.2 μm thick a-SiN_x:H at a temperature of 150 °C as the insulating and passivation layer. After photoresist patterning, the contact-hole through the a-SiN_x:H was opened, finally, the second Al interconnection was evaporated. Each pair of pin diodes, i.e., E_{1y} (E_{1x}) and I_{1y} (I_{1x}), E_{2y} (E_{2x}) and I_{2y} (I_{2x}), are connected back-to-back, by measuring the output photocurrent difference of these pairs of two back-to-back connection photodiodes, i.e., (E_{1y} - I_{1y}) / (E_{1x} - I_{1x}), (E_{2y} -I_{2y}) (E_{2x} - I_{2x}), the position and the orientation of a contrast ed can be extracted. The detail operation principle of hollo FOQUOD was published elsewhere [7]. When a contrast ed lies across the detector as shown in Fig. 2(a), the output si nals (the short circuit currents) of F1 and F2 can be measure Thus, two orientations θ_1 and θ_2 of the contrast edge with r spect to the horizontal line are measured by F1 and F2, respe tively. Conceptually, θ_1 is equal to θ_2 and it is considered as contrast edge. But if an image with an angle passing throu this device as shown in Fig. 2(b), the measured orientations and θ_2 are not equal and the image is considered as an angl Therefore, the angle positions of an arbitrary image can th be extracted.

3. RESULTS AND DISCUSSION

Fig. 3 shows the measurement results of the error signal - θ_1 when a contrast edges with different angle with respect the horizontal line through this device. The output photocu rents are in the range of μA under an illumination of 0 AM1. There are five test samples whose edge orientatio with respect to the horizontal line are 0°, 18°, 45°, 63° and 9 respectively. The maximum difference value is 6 degree shown in Fig. 3 when the contrast edge with a 63° orientati passing the boundary of this device. Therefore, a 6° error to erance is given to set the boundary between the criterion of t "edge" and "angle". In other words, if the absolute differen of orientation obtained from F1 and F2 is larger than 6° t contrast feature detected by this device is considered to be a "angle" feature. Fig. 4 shows the accuracy of detecting a angle feature passing through this device. During the test, t

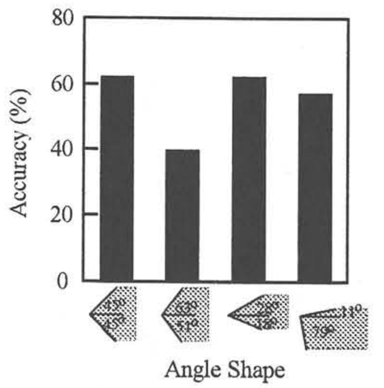


Fig. 4 The accuracy of detecting an angle feature passing through the double FOQUOD. During the test, the double FOQUOD is equally divided into sixteen squares, the tip of the test angle is moved to each of the center of the sixteen squares. The 16 measured results are averaged to obtain the percentage of accuracy.

double FOQUOD is equally divided into sixteen squares, the tip of the test angle is moved sequentially to each of the center of the sixteen squares and measure the output current of the F1 and F2 cells. The angle is a combination of two contrast edges with angles α and β respect to the horizontal line. There are four test samples as shown in Fig. 4, a 90° angle with $\alpha = 45°$ and $\beta = -45°$ contrast edges (45°/-45°), a 114° angle (63°/-51°), a 46° angle (28°/-18°) and a 90° angle (11°/-79°). If the threshold degree for distinguishing "edge" from "angle" is set to 6°, the average accuracy by summing up 16 measurements are beyond 55%.

Now, if this double FOQUOD is used as a single pixel to construct a two-dimensional array, most of the angle positions of a random pattern can be detected by this array and the rest can be extracted through the assistance of software and the data from neighboring cells.

4. CONCLUSION

A double FOQUOD device using a-Si:H which can extract angle positions of a random pattern has been fabricated successfully. The accuracy of detecting the angle positions of a random feature falling on 16 different locations of a double FOQUOD is beyond 55%. It is the first time for pattern recognition that a hardware device can directly extract the angle position of an image.

5.ACKNOWLEDGMENT

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