Evaluation of Hardware Oriented MRCoHOG using Logic Simulation

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Keywords: MRCoHOG, Hardware Oriented Algorithm, Human Detection.

Abstract: Human detection require high speed and high accuracy processing. One of the high performance techniques of the detection is multi-resolution co-occurrence histogram of oriented gradients (MRCoHOG). Since the calculation of co-occurrence requires a huge amount of processing resources, it is difficult to realize real-time human detection with MRCoHOG. Accordingly, hardware implementation is considered to be effective. In this paper, a hardware oriented MRCoHOG is proposed. In the proposed method, we simplify complicated calculation such as multiplications and square root operation for efficient hardware implementation. Experimental results show that the proposed method achieves better human detection rate than the ordinary method. Moreover, MRCoHOG is implemented in a digital circuit with the proposed method. According to logic simulation of the proposed circuit, the processing speed of the hardware implementation is 466 times higher than the software implementation.

1 INTRODUCTION

Human detection is a technique for cutting out a human area from an input image, and has to process the image at high speed and with high accuracy. Human detection has two processes, a feature extraction and a classification. Detection accuracy depends on these performances. In this research, we focus on the feature extraction processing and aim at high speed processing by a dedicated hardware using feature extraction method with high detection rate.

Human detection extracts common features of human from many kinds of image data. From image data of photograph, color information of each pixel is obtained. However, human detection using color information is very difficult, since the color of clothes and background changes depending on the pictures. Therefore, capturing the features of human is effective in human detection. Luminance gradients are forced on as feature. One of the luminance gradient features is histogram of oriented gradients (HOG) (Dalal and Triggs, 2005). HOG use gradient distribution of local area. This feature is robust for postural and illumination changes. Co-occurrence histogram of oriented gradients (CoHOG) (Watanabe, Ito and Yokoi, 2009) feature is an improved feature of HOG. CoHOG feature uses co-occurrence gradient direction of local area. This feature is able to present more complicated shapes than HOG features. In this study, we use multi-resolution co-occurrence histogram of oriented gradients (MRCoHOG) (Iwata and Enokida, 2014) feature for human detection. MRCoHOG feature is revised version of HOG and CoHOG features. MRCoHOG has high precision in human detection. However, the real-time human detection using MRCoHOG and CoHOG is difficult because the calculatoin of co-occurrence needs a great number of processing resources. Therefore, hardware implementation is required to realize real-time human detection with MRCoHOG.

In this paper, a hardware oriented MRCoHOG is proposed. In the proposed method, simple calculations are employed instead of complex ones to minimize circuit size. Based on the hardware oriented algorithm, we design a digital circuit of MRCoHOG described by Verilog Hardware Description Lauguage. The designed circuit is evaluated by a logic simulation and compared with a software

Yamasaki Y., Ooe S., Suzuki A., Kuno K., Yamada H., Enokida S. and Tamukoh H.
Evaluation of Hardware Oriented MRCoHOG using Logic Simulation.
DOI: 10.5220/0006165803410345
In *Proceedings of the 12th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications (VISIGRAPP 2017)*, pages 341-345
ISBN: 978-989-758-226-4

implementation at the point of processing speed. As a result of comparison, the proposed circuit operates 466 times faster than the processing speed of software implementation.

2 IMAGE FEATURES

In human detection tasks, classification accuracy from images is the most important requirement. The accuracy depends on effectiveness of image feature extractors and accuracy of classification models, since human detection process is divided into feature extraction part and classification part.

In this paper, we focus on the image feature extractor employing luminance gradient form local region. The extractor of the detection should consider about changes of poses and closes of human. Therefore, the detection uses features from local region which don’t be effected by body direction and posture. For the human detection, it is quite difficult to detect with collar information, so that most of the methods employ luminosity and grasp shape with feature based on luminance gradient.

2.1 HOG

HOG is gradient orientation based feature. In order to extract HOG from an input image, firstly, gradient directions at every pixels are calculated. Secondly, histogram of each direction in a local area is calculated. Finally, HOG feature is created by concatenating the histograms of all local areas. Figure 1 shows histogram on HOG.

HOG has two advantages for human detection. One is robustness against illumination variance since gradient directions of local areas do not change with illumination variance. Another one is robustness against deformations which generate a small amount of histogram value conversion.

2.2 CoHOG

CoHOG is an extended feature of HOG and has a high-dimensional feature as shown in Fig. 2. This feature uses a pair of gradient directions to make a histogram. The combinations of neighbour gradient directions can express shapes in detail. Via this idea, CoHOG shows better performance than HOG at the point of discrimination.

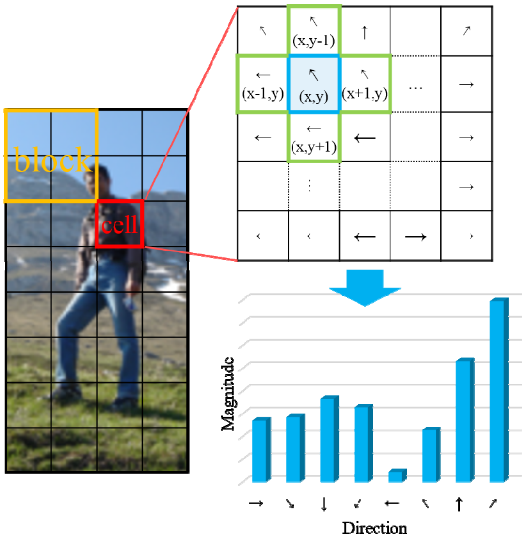

Figure 1: Histogram on HOG.

2.3 MRCoHOG

MRCoHOG feature uses multi-resolution images to calculate gradient directions. MRCoHOG feature makes two-dimensional histogram of co-occurrence gradient directions as shown in Fig. 3. MRCoHOG is to observe the combinations of the gradient directions with different resolutions, thus features over larger areas without changing filter sizes.

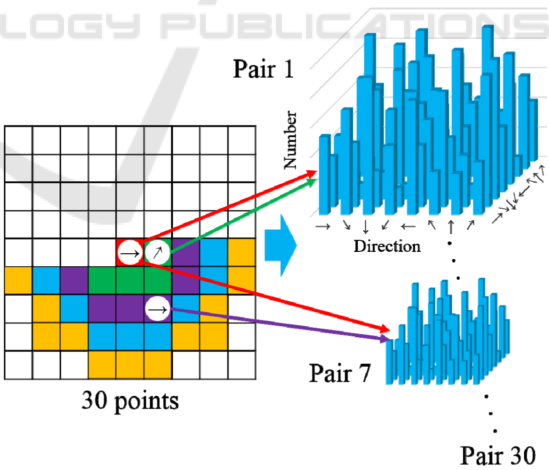

Figure 2: Two-dimensional histogram on CoHOG.

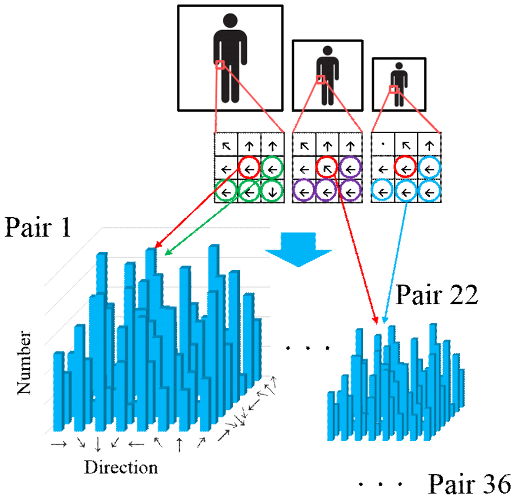

Figure 3: Two-dimensional histogram on MRCoHOG.

3 PROPOSED METHOD

A hardware implementation of MRCoHOG realizes high speed processing and low power consumption. However, MRCoHOG consists of complex calculations such as multiplication, square root and arctangent. They require large circuit area. To overcome the problem, we propose a hardware oriented MRCoHOG algorithm with simple calculations.

3.1 Gradient Magnitude

Gradient magnitude can be calculated by using Euclidean distance (Eq. (1)). The method includes a square root calculation and multiplications, therefore inappropriate for hardware implementation. We instead employ a hardware oriented technique without neither a square root nor multiplications, the Manhattan distance (Eq. (2)).

$$\mathrm{m(x,y)} = \sqrt{f_x(x,y)^2 + f_y(x,y)^2} \tag{1}$$

$$\mathrm{m(x,y)} = |f_x(x,y)| + |f_y(x,y)| \tag{2}$$

Here, Eqs. (3) and (4) represent the difference in luminance between $f_x(x,y)$, $f_y(x,y)$ where, $L(x,y)$ is the luminance at point(x,y).

$$f_x(x,y) = L(x+1,y) - L(x-1,y) \tag{3}$$

$$f_y(x,y) = L(x,y+1) - L(x,y-1) \tag{4}$$

Table 1: Conditional branch of gradient direction.

Direction		$f_x(x,y)$	$f_y(x,y)$	$\lvert f_x(x,y)\rvert - \lvert f_y(x,y)\rvert$
0°- 45°	→	> 0	≧0	> 0
45°- 90°	↘	> 0	≧0	≦0
90°- 135°	↓	≦0	> 0	< 0
135°- 180°	↙	≦0	> 0	≧0
180°- 225°	←	< 0	≦0	> 0
225°- 270°	↖	< 0	≦0	≦0
270°- 315°	↑	≧0	< 0	< 0
315°- 360°	↗	≧0	< 0	≧0

Table 2: INRIA person dataset using human detection.

Training Image		Test Image		Resolution
Positive	2416	Positive	1126	32x64
Negative	12288	Negative	4840	[pixels]

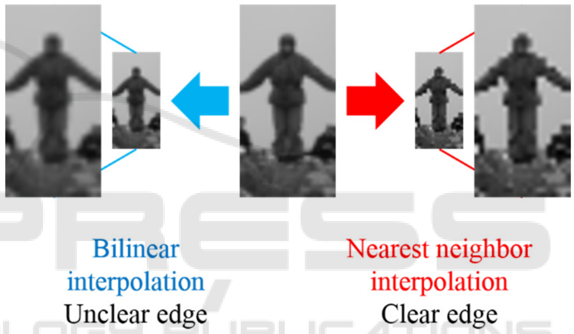

Figure 4: Image resize method.

$$\tan^{-1}\frac{f_y(x,y)}{f_x(x,y)} \tag{5}$$

3.2 Gradient Direction

In the proposed method, arctangent is elected to earn gradient direction. By conditional branch of eight directions as shown in Table 1, it is eliminated to calculate arctangent (Eq. (5)).

3.3 Image Resizing

For hardware oriented image resizing, we replace the original bilinear interpolation with the nearest neighbour interpolation. The nearest neighbour interpolation can possibly simplify the resizing process. Figure 4 shows resizing image.

4 EXPERIMENTAL RESULTS

4.1 Software Implementation

Performance of MRCoHOG is validated via software implementation before hardware implementation of it, since the hardware implementation demand more number of processing than software implementation.

We compared results of the human detection rate with the proposed method to the ordinary method. The dataset used in these methods is INRIA Person dataset (Dalal and Triggs, 2005). Table 2 shows details of image dataset using training and test images. MRCoHOG uses three different resolutions (original, 1/2 and 1/4). The discriminator used in our approach is Real AdaBoost (Shapire and Singer, 1999). We use 500 classifiers in Real AdaBoost. For quantitative evaluation of detection rate, we use the Receiver Operating Characteristic (ROC) curve. Vertical axis shows detection rate, and horizontal axis shows false positive rate in this ROC curve. When two methods are compared with this ROC curve, the method which curve passes more left and upper zone of the figure than another one shows higher performance than another one.

Figures 5, 6, and 7 show each of the results where the ordinary method was compared with each of the hardware oriented gradient magnitude, image resize, and MRCoHOG where both of hardware oriented gradient magnitude and image resize are integrated. From Fig. 5, the proposed method performed as the same quality as the original method. The proposed resize method detected human with higher accuracy than original one in Fig. 6, since edges of the images after changing resolution were appeared clearly via the nearest neighbour interpolation. Figure 7 shows a comparison result of the proposed method combining the gradient magnitude and resizing with the ordinary MRCoHOG. From the result, the proposed hardware oriented MRCoHOG realized high performance than the ordinary MRCoHOG. In addition, from the view point of hardware implementation, the proposed method simplified the whole calculation process of MRCoHOG.

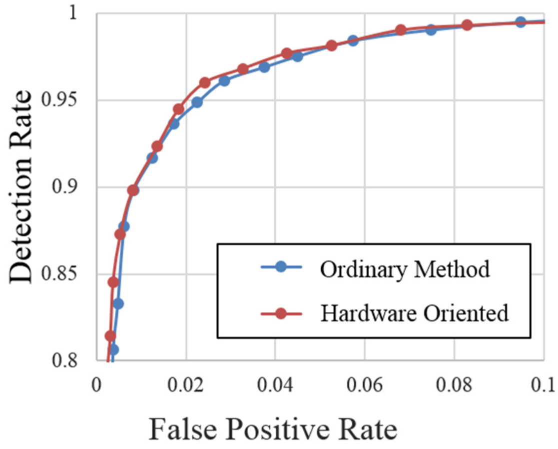

Figure 5: Human detection using hardware oriented gradient magnitude.

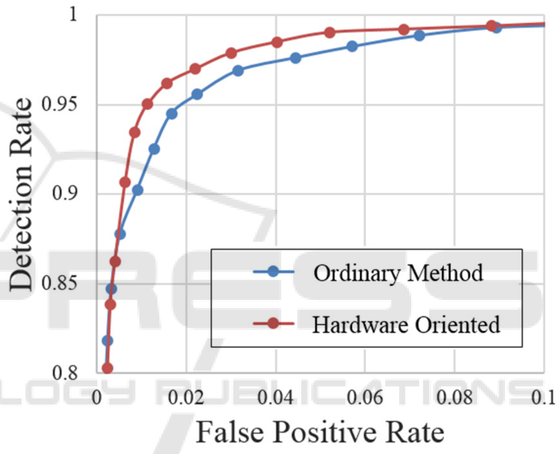

Figure 6: Human detection using hardware oriented resizing.

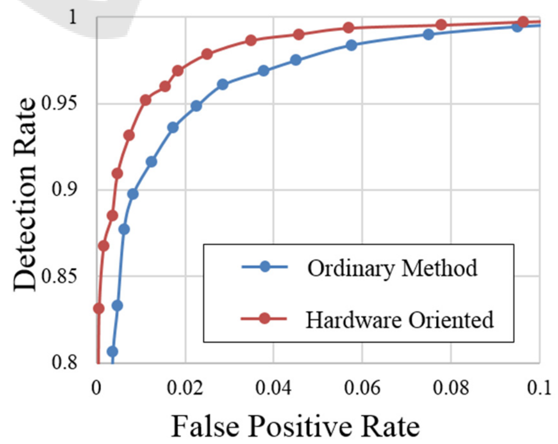

Figure 7: Human detection using hardware oriented MRCoHOG.

4.2 Hardware Implementation

With software validation, the performance of the proposed method was better than the ordinary method, hence digital circuit was implemented with proposed method.

The circuit is described by Verilog Hardware Description Language, and Veritak Verilog simulator is use for logic simulation to evaluate the circuit. In the simulation, image data is assumed as an input data.

In the proposed circuit, there are five main modules that contain several submodules. The entire circuit is shown in Fig. 8. In these circuits, the size of the input image data is changed to half and quarter size. Every three size of the inputs are processed in parallel.

The roles of each circuit is described in the list below.

(a) Size (1/2, 1/4) Module: The resizing of the input image
(b) 3 Line Buffer Module
(c) Calcurate Module: The calculation of magnitude and direction
(d) Synchronize Module: The synchronization of three inputs
(e) Histogram Module: The creation of two dimensional histogram

In the simulation phase, the output of the proposed design circuit could be regarded as a regular value as MRCoHOG, therefore the circuit seem to be able to calculate the value of MRCoHOG regularly. Moreover, from the result of comparison between logic simulation and software implementation, the circuit can calculate MRCoHOG 466 times faster than software implementation. Software processing takes 11.42[s]. Hardware processing takes 24.49[ms].

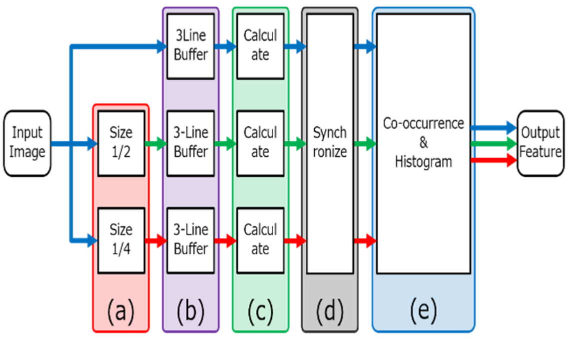

Figure 8: Human detection using hardware oriented gradient magnitude.

5 CONCLUSIONS

Since human detection need high accuracy and speed method for image feature extraction, we proposed the hardware oriented method based on MRCoHOG. In the proposed hardware oriented MRCoHOG, we replaced the complicated calculation such as multiplications and square root operation by simplified calculation for hardware implementation. From experimental results of human detection, the effectiveness of proposed method was clarified in the detection rate. The result of hardware implementation and its logic simulation, processing speed of the proposed circuit was 466 times faster than the software implementation. Future work will find out appropriate discriminator such as neural networks and Real Adaboost and will construct high accuracy and high perception real time human detection system.

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