Enhanced HoG Technique for Pedestrian Detection Based on Quarter Cell

Kim Pyeongkang, Kim Hyunghun, and Kim Taewoo
INNODEP/R&D Planning Team, Seoul, Korea
Email: {david, josephkim, davidkim}@innodep.com

***Abstract*—There is a high level of interest in pedestrian detection systems based on worldwide acknowledgement of pedestrian safety, and the need for research in this area is increasing. The HoG based pedestrian detection method proposed by Dalal and Triggs has been recognized as being less sensitive to the clothing and poses of pedestrians and also changes in lighting and is therefore one of the main methods used for pedestrian detection. But because the HoG based method requires a significant amount of computations, it is difficult to implement this method in real-time. Therefore, this paper calculates the histogram of only needed cells to suggest HoG based on Quarter Cell, which has shortened the calculating process and it turns out that there is no significant difference in detectability factor whereas the time spent to get the results has decreased.**

***Index Terms*—pedestrian, pedestrian detection, intelligent system, HoG**

I. Introduction

There is a high level of interest in pedestrian protection systems through worldwide acknowledgement regarding the safety of pedestrians, and the need for research in this area is increasing. Methods for extracting features to detect pedestrians that are heavily being researched include the Haar wavelet [1] based method, which is a method that utilizes the directionality of slopes, and the LRF (Local Receptive Field) method etc., and these methods can be categorized into to the SVM (Support Vector Machine) [2] models, neural network [3] models, and the AdaBoost algorithm [4]. Out of these methods, the HoG based pedestrian detection method [5] proposed by Dalal and Triggs that has been recognized as being less sensitive to both changes in lighting and also the clothing and poses of people and is the most widely used method [6].

Therefore, in this paper, of which to provide a solution to the problem, I would like to design a speed enhanced pedestrian walking algorithm by executing triangle distance between steps with Quarter Cell-based, which reduced unnecessary computation of the cell to reduce overall HOC computation

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II. Designing a Pedestrian Detection Method Using HoG Based Quarter Cell

A. Problems with Previous Research Studies

The most important factor in the field of video based pedestrian detection is the high detection rate and speed of detection. Because pedestrians can be difficult to detect due to various reasons including external appearance, lighting and background etc., the characteristics that enable pedestrian detection must be clearly distinguishable from any other characteristics and must also be minimally affected from external influences such as noise.

Out of the various characteristics that are used to detect pedestrians, because there is a relatively small influence from changes in lighting and the clothing and postures of people, these characteristics are widely used in pedestrian detection. However, these methods require significant amounts of calculations and also have the drawbacks of slow detection speeds [7]-[9].

Therefore in this section, of which to provide a solution to the problem, I would like to design a speed enhanced pedestrian walking algorithm by executing triangle distsnce between steps with Quarter Cell-based, which reduced unnecessary computation of the cell to reduce overall HoG computation.

B. Extracting HoG Algorithm Feature

Fig. 1 shows the overall process of extracting HoG algorithm features. The first step is to calculate the value of the slope. The most common method is to apply a one-dimensional center point discrete differential mask in both the horizontal and vertical directions as shown in formula (1)

$$D_X = [-1\ 0\ 1], D_Y = [-1\ 0\ 1]^T \qquad (1)$$

Then when image I is given, convolution calculations are conducted on both the mask and image of formula 3.1 in the x and y directions.

The second step is to calculate the magnitude and the direction of the slope for which the I_X and I_Y values calculated in step 1 are used. The third step is related to calculating the cell histogram. The direction of the slope are calculated using the calculations of the slopes derived using the pixel values of each of the divided cells, and these values propagate to each of the direction histogram ranges that are configured as bin numbers.

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The fourth step requires local normalization, which in turn requires the magnitude of the slopes to be grouped in terms of connected blocks that are connected in bigger and more spacious blocks in order to take into consideration the changes in the lighting and contrast. Through this process, the features of the HoG algorithm are populated into cell histogram vectors that normalize cells of the block scope. The L2-Hys method was used in this research study. The L2-Hys is calculated using the L2-norm, and the maximum value for v is 0.2. n is the number of pixels included in the block and ε is a constant that does not significantly affect the results that is used to prevent error. Therefore because the overlap ratio was set as 50% based on a 64×128 pixel image in this research study, there are a total of 7×15=105 blocks, and because each cell has 9 bins, each block has 4×9=36 feature vectors. In this research study a total of 105×4×9=3780 features are deduced.

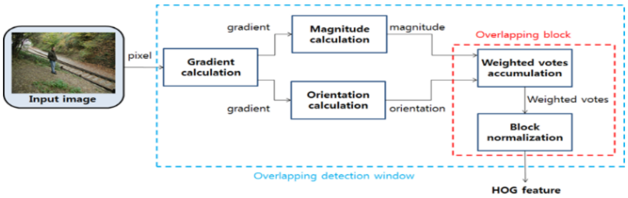

Figure 1. HoG

C. Quarter Cell Based Tri-linear Interpolation Method

Each other cells take on a rate slope value and direction. To decrease the aliasing that occurs due to the difference in the directions between each of the adjacent cells, the Quarter Cell based tri-linear interpolation method is used on entire block units.

$$h(x_1,y_1,\theta_1) \leftarrow h(x_1,y_1,\theta_2) + |\nabla f(x,y)|\left(1-\frac{x-x_1}{d_x}\right)\left(1-\frac{y-y_1}{d_y}\right)\left(1-\frac{\theta(x,y)-\theta_1}{d_\theta}\right),$$

$$h(x_1,y_1,\theta_2) \leftarrow h(x_1,y_1,\theta_2) + |\nabla f(x,y)|\left(1-\frac{x-x_1}{d_x}\right)\left(1-\frac{y-y_1}{d_y}\right)\left(\frac{\theta(x,y)-\theta_1}{d_\theta}\right) \quad (2)$$

Formula (2) is a formula for Quarter Cell based tri-linear interpolation. Here x and y are location values, and $\nabla f(x,y)$ is the rate slope value for the Gaussian weight value. d_x and d_y refer to the size of the cell and d_θ is π/9.

However, because each cell only influences the slope rate value of itself, calculations must be made for all 4 cells based on each block.

Therefore in this research study, compared to the previous cell calculation method, but categorizing cells into 4 types and by omitting the histogram calculations of cells that are insignificant and further away from the target cell, a Quarter Cell based tri-linear interpolation method that reduces the number of tri-linear interpolation calculations is proposed. The proposed Quarter Cells can be categorized into 3 types. These categorizations include the Main Cell, which is located closest to the enter, and the Sub Cell, which is located in the center, and the Corner Cell, which is located furthest from the center.

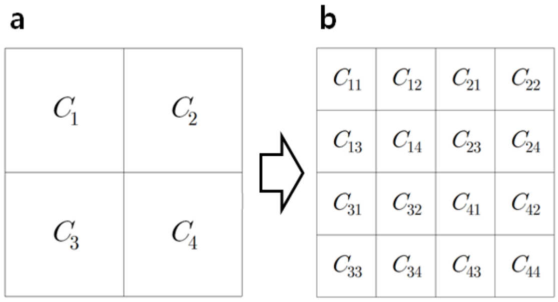

Figure 2. Quarter cell

As shown in Fig. 2, each block contains 4 cells.

Each of the C_1 cells includes 4 Quarter Cells. $(C_{i1}, C_{i2}, C_{i3}, C_{i4})$

And each of the Corner Cells are made up of C_{11}, C_{22}, C_{33} and C_{44}.

The Main are made up of $C_{14}, C_{23}, C_{41}, C_{32}$.

The Sub Cells are made up of $C_{12}, C_{21}, C_{24}, C_{42}, C_{43}, C_{34}, C_{31}, C_{13}$.

The Quarter Cell based tri-linear interpolation method that is proposed in this research study has the 3 following characteristics.

1) The Corner Cell is located on the corner of the block, and the slope of the Corner Cell is only used for the calculation of the cell's own histogram. In other words, the slope of $C_{11}, C_{22}, C_{33}, C_{44}$ is only used to calculate the histogram for C_1, C_2, C_3, C_4.

2) Because the Main Cell is located in the center of the block, it is adjacent to the other cells. Therefore the slope of the Main Cell is used for the calculation for the histogram of all cells.

3) For the case of Sub Cells, because these cells are adjacent with special cells, the slope of the Sub Cell is used to calculate its own histogram and the histogram of cells that are adjacent.

For example, C_1 is included for the case of C_{13} for the Sub Cells of C_{13} and they are adjacent to C_3. Therefore it is used for the calculation of the slope of C_{13} and the histogram of C_1 and C_3. And it can also be confirmed that this can be used regardless of C_2 and C_4.

Through the 3 characteristics above, for Corner Cells, only 1 Quarter Cell is required and for Main cells, all 4 cells are required. Also for the case of Sub Cells, all 4 adjacent cells are required. This can be expressed as shown in Formula (3).

$$h_1 = \sum_{i=1}^{4} hist(C_{1i}) + hist(C_{21}) + hist(C_{31}) + hist(C_{23}) + hist(C_{41}) + hist(C_{32}) \quad (3)$$

Formula (4) is the formula for the previous cell calculation method.

$$h_1 = \sum_{i=1}^{4} hist(C_i) = \sum_{i=1}^{4}\sum_{j=1}^{4} hist(C_{ij}) \quad (4)$$

As shown in Formula (3), for the method that proposes calculating the histogram 16 times for the block required to conduct tri-linear interpolation, this method can be confirmed to have been reduced to 9 calculations.

III. Implementation and Tesying

To implement and evaluate the performance, this testing was conducted using Window 7 OS on an Intel Core2 Duo E8400 2.99 GHz machine with 4096 MB of RAM. The INRIA Person Dataset was the pedestrian dataset to be referenced for implementation and performance evaluation. The INRIA Person Dataset is made up of a total of 5,213 images, which included 64 x 128 pixel dimensions images of pedestrians and other images of various sizes that are not of pedestrians. Fig. 3 shows the example screens. To evaluate the pedestrian detection algorithm that utilizes HoG implemented in this research, Matlab 2012b was used to comparatively evaluate the results of this research with those of previous research. Fig. 3 shows the example screens.

Figure 3. Screen embodiment

The Miss rate and FPPW (False Positive Per Window) performance indices were used for evaluation. FPPW is one method used to express false detection rates and expresses the average number of false detections for each window. For example, when examining 10,000 windows with a detection device, if there are 5 false positives, the FPPW is measured to be 5/10,000. In other words FPPW is used as an index to measure how many false positives actually occur. Formula (5) shows a formula to calculate the Miss rate and FPPW. Also the detection rate, which is a very important index in this research study, was defined as 'detection rate = 1 － miss rate'

$$\text{FPPW} = \frac{False\ Positives}{False\ Positives + True\ Negatives}$$

$$\text{missrate} = \frac{False\ Negatives}{True\ Positives + False\ Negatives} \qquad (5)$$

A. *The Performance Evaluation for the Quarter Cell Based Tri-linear Interpolation Method*

Fig. 4 shows the Quarter Cell based HoG graph that proposes the HoG that uses the previous tri-linear Interpolation method, and Table I is a table showing the comparison between the detection rates and speed of detection between that of the previous algorithm and the proposed algorithm. As show in Table I, the HoG using the proposed Quarter Cell based method has an average detection time of 17.954ms, which shows an 11% speed improvement over that of the previous algorithm, which has an average detection time of 20.174ms. Also as shown in Table I, while when testing based on 10^{-3} FPPW, the performance compared to the previous algorithm was relatively decreased as can be seen from the proposed algorithm based on 10^{-4} FPPW standards is 94.93%, and the previous HoG algorithm is 94.79%, the proposed algorithm based on 10^{-5} FPPW standards is 88.95%, and the previous HoG algorithm is 89.71%, the proposed algorithm based on 10^{-4} FPPW standards is 83.55%, and the previous HoG algorithm is 83.14%, it can also be confirmed that for the 10^{-5} FPPW standard case and the 10^{-3} FPPW standard case the performance in increased marginally. In conclusion, it can be confirmed that the proposed algorithm, has minimal performance difference when compared to the previous HoG algorithm while the speed of the algorithm has increased.

TABLE I. Performance Comparison

Categorization	Proposed Algorithm	HoG
Pedestrian Detection rate (10^{-5} FPPW)	83.55%	83.14%,
Pedestrian Detection rate (10^{-4} FPPW)	88.95%	89.71%,
Pedestrian Detection rate (10^{-3} FPPW)	94.93%	94.79%
Average Detection Time(ms)	17.954	20.174

To design the algorithm proposed in this research study, first, the characteristics of the algorithm were extracted using HoG, and by conducting Quarter Cell based tri-linear interpolation, the speed of the calculations was improved.

Using the Person Dataset, the proposed pedestrian detection algorithm and the previous pedestrian detection algorithm were compared, and the results confirmed that when compared to the previous method, the HoG that applied the Quarter Cell based tri-linear interpolation had an 11% increase in speed without a detectable difference in terms of performance.

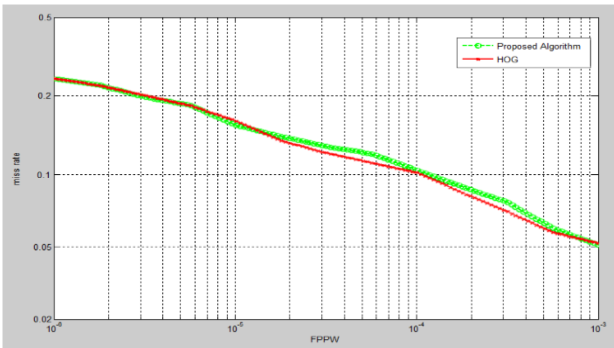

Figure 4. Performance comparison

IV. Conclusions

Out of the various characteristics that are used to detect pedestrians, because there is a relatively small influence from changes in lighting and the clothing and postures of people, these characteristics are widely used in pedestrian detection [10], [11]. However, these methods require significant amounts of calculations and also have the drawbacks of slow detection speeds [12].

Tri-linear interpolation, which has a critical role in increasing the detection rate requires the highest amount of calculations.

Therefore in this section of this research study, to address the two problems mentioned above, first by conducting a Quarter Cell based tri-linear interpolation method, which reduces the number of unnecessary cell calculations, and by reducing the total number of HoG calculations, a pedestrian detection algorithm with increased speed was designed.

To evaluate the performance of the pedestrian detection algorithm designed and implemented in this research study, the widely used INRIA Person Dataset, which is made up of positive images that are 64×128 pixel dimensions and negative images of various sizes, was referenced.

Previous pedestrian detection algorithms and the pedestrian detection algorithm proposed in this research study were comparatively evaluated using the Person Dataset, and the results of the analysis confirmed that compared to previous pedestrian detection algorithms, the algorithm that used Pedestrian Detection based on Quarter Cell algorithm showed a 11% increase in speed without a detectable difference in terms of performance.

It is considered that this increase in performance of pedestrian detection will be beneficial and widely applicable in areas such as the automotive industry and the robotics industry etc.

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Pyeongkang Kim was born in Seoul, Korea on July 30th in 1987. Kim studied Science of public administration at Korea National University of Transportation and acquired bachelor’s in 2012. Kim proceeded to the graduate school of Gachon University and acquired master’s in 2015. Kim’s major field of study was Mobile Software.

He is an Assistant Researcher Engineer of Innodep Technology Laboratory for three years. He is responsible for research regarding video analytics and intelligent systems.

Mr. Kim is the member of KIPS and KIISE. His recent article was about intelligent system and was published as the title of “Design and Evaluation of Improved Pedestrian Detection Algorithm Using HoG-UDP” in CUTE 2016. His Areas of Interest also include Video & Image Processing.

Hyungheon Kim was born in Korea on April 29th in 1981. Kim studied computer science at Kyungwon University and acquired bachelor’s in 2008. Kim proceeded to the graduate school of the same university and acquired master’s in 2010. Kim’s major field of study was computer network.

He is a senior researcher and team manager of Innodep Technology Laboratory for five years. He is responsible for planning R&D strategic and researching video data processing and management.

Mr. Kim is the member of KIISE. He published papers regarding video analytics and heterogeneous video management system. His recent article was about intelligent monitoring system and was published as the title of “The Design of Object-of-Interest Extraction System Utilizing Metadata Filtering from Moving Object” in KIISE.

Taewoo Kim was born in Seoul, Korea on March 20th in 1987. Kim studied electronic engineering at Korea Aerospace University and acquired bachelor’s in 2012. Kim proceeded to the graduate school of the same university and acquired master’s in 2014. Kim’s major field of study was radar signal processing.

He is on military service as a research assistant at Innodep Technology Laboratory for three years. He is responsible for national funded research projects and has been doing research regarding video analytics and intelligent monitoring systems.

Mr. Kim is the member of KIEES and KIISE. He published an article regarding wireless interference effects as the title of “Interference Influence Analysis on the Interoperability in the Combined Military Communication Systems” in KIEES in 2014. His recent article was about intelligent monitoring system and was published as the title of “The Design of Object-of-Interest Extraction System Utilizing Metadata Filtering from Moving Object” in KIISE.

