BIO-INSPIRED NEUROMORPHIC IDENTIFICATION OF PEDESTRIAN AND OBJECT FOR THE ROAD USER SAFETY

Woo Joon, Han
Il Song, Han
KAIST, Korea, i.s.han@kaist.ac.kr
Paper Number 11-0217

ABSTRACT

There has been much research and development in pedestrian detection to minimize accidents. The fast changing environment presents a challenge for reliable detection. In this paper, an algorithm inspired from human eye was implemented. The detection of pedestrian from an image taken from a moving car and a second deck of a moving bus proved to be successful with same algorithm even the condition of the image taken was quite different. The feasibility of applying this idea is further extended when it can be implemented electronically using 0.18um CMOS technology.

INTRODUCTION

The pedestrian detection techniques in real-world images have emerged as a solution to protect pedestrians against fatal accident. The vision-based pedestrian detection is very challenging due to the wide range of outdoor lighting condition and pedestrians' appearance. In this paper, we propose a pedestrian detector based on bio-inspired neuromorphic system of mimicking human or animal, for the robust and reliable operation on the road. The video image or still image of pedestrians on the road is analyzed by a neuromorphic system, which is based on the Hubel and Wiesel's experimentation of cat's visual cortex and the spiking neuron of Hodgkin-Huxley formalism. The research of visual signal processing aims to identify pedestrians or other vulnerable non-occupant road users of bicyclist or motorcyclist. The current development stage is the recognition of pedestrians crossing the road or bicyclist/motorcyclist on the road. The detection of pedestrian and other vulnerable road users is monitored using the CCTV video image taken from the urban road intersection.

The analysis methodology is developed by mimicking the principle of visual cortex with similar robust characteristics, while there is practical feasibility of VLSI implementation for low cost device. The directional elements in images are utilized as in Hubel and Wisel's experimentation, and the neural networks with template as well as the histogram analysis are used to recognize the pedestrian or vulnerable objects.

The successful detection of a pedestrian or bicyclist demonstrates the feasibility of adopting the video-based road user detection, with video taken from commercial IP CCTV camera as database in the experiment. The challenge of abrupt illumination change is managed by mixed processing of neuromorphic and frame difference.

The video sequence, with resolution of 720x480 and 30 frames per second, is successfully evaluated for detecting the pedestrian, the bicyclist, and the motorcyclist on the road. During the sequence, the video sample is taken at different time of the day with different illumination conditions. The human head is also identified regardless of the facial direction, while the wheel of bicycle or other objects is successfully recognized. The robust and flexible detection of objects is enabled by the particular directional image processing together with neural weight template. The neuromorphic vision system is applied to the video image of pedestrians taken by the commercial car black box, while the vehicle is in motion at various locations of Korea and UK.

The neuromorphic vision based pedestrian detection system targets to develop the pedestrian protection system, which warns the driver from the road infrastructure or the on-vehicle system. The neuromorphic system improves the robustness and reliability of the vision-based pedestrian detection for the wide range of application environment.

Bio-inspired detection

The environment of the pedestrian may differ greatly between each person since the vehicle is in motion. So a robust detection algorithm is needed to perform accurately under this fast changing environment. Much of computer vision algorithms are effective in their specific usage, however they lack the robustness of human vision and for most times will underperform in varied conditions. [1]

Although there is not a definite model of visual cortex, Hubel and Wiesel's research on cat's striate cortex confirmed the idea on the functioning of simple cell [2]. It is from this discovery which motivated various theories of object recognition from characters to complex natural images [3]. These researches on neurophysiology introduced the principles of biologically plausible electronic implementation. One of the electronic implementation is the Hodgkin and Huxley's model of neuron which is utilized in this paper to show feasibility of implementation of proposed bio-inspired visual processing electronically. The motivation for it was found from the result of the well-known experimentation of simple cell by Hubel and Wiesel as shown in figure 1. By mimicking the simple cell, similar robustness of visual cortex can be achieved.

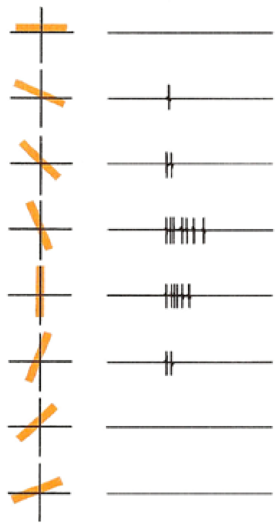

Figure 1. Response of the cat's cortex when a rectangular slit of light of different orientations is shown [1]

<u>**Neuromorphic neuron based on voltage-controlled CMOS conductance**</u> The Hodgkin-Huxley (H-H) is a widely adopted idea of neuron's biophysical characterization as shown in figure 2. H-H formalism is not used as much in neural networks as it does not give any major advantages however the asynchronous spikes are considered as principle element of high level or large scale neural computing system.

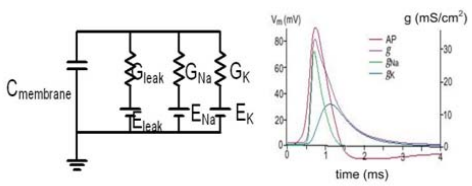

Figure 2. An electrical equivalent circuit of neuron, H-H formalism where the asynchronous spike of a neuron as shown on the right can be reproduced. [4]

A circuit of Fig. 3a was proposed as a voltage-controlled linear conductance circuit by a PMOS transistor and a pair of identical NMOS transistors M1 and M2, while the conductance of MOS transistors is one of essential components in the analogue circuit design. The circuit of Fig. 3 has been investigated for various neural networks applications, from implementing synapses to neurons [5, 6].

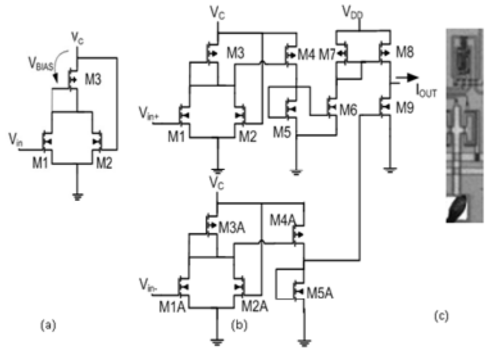

Figure. 3a. Voltage-controlled linear conductance by a pair of MOSFETs in the triode region, b. the tunable linear transconductance circuit, c. the chip photograph of CMOS transconductor.

The empirical mathematical formulae of conductance element in the formalism is expressed as (1) where b is the sigmoid function of membrane potential. And V_m is a membrane potential and the overall dynamic modeled by an Action potential and related ionic conduction.

$$\mathbf{G_{ion} = G_{ionmax} \cdot x}$$

$$\mathbf{dx/dt = \alpha(b - x)}$$

$$\mathbf{i_{ion} = G_{ion}(V_m - E_{ion})} \qquad (1)$$

Functional components of eq 1 are controlled conductance, multiplication, addition (or subtraction), and differential equation. The differential equation in eq 1 can be implemented by the low pass filter, which induces a delayed response. From these relationships dynamic behavior of biological neuron can be implemented electronically by the ion-based conductance controlled by membrane potential as shown in figure 3.

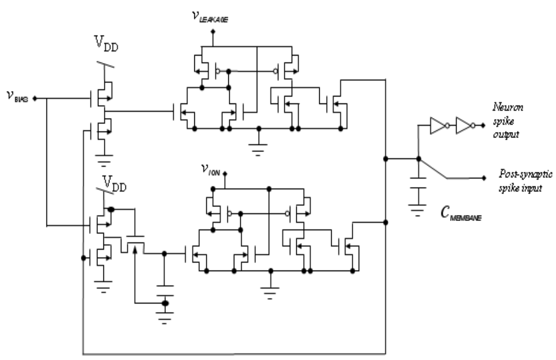

Figure 4. Neuromorphic implementation of a neuron.

The implemented system was simulated with different orientation inputs as it is believed that the tuning properties of orientation selectivity plays key role for perception in visual cortex as it was shown in figure 1. For the simulation, a tuned feature map of 5 x 5 synaptic weights, shown in figure 5, is based on the reference stimulus to match, with the minor adjustment depending on the output was prepared to mimick the orientation selectivity property of the simple cell. The synaptic weights are in the ratio of 1:-0.6:0.1 for black: grey: white respectively. The stimulus were six 50 x 50 pixel sized rectangles at different angles as to give same effect as the inputs give to the cat in Hubel and Wiesel's experiment. The result of stimulation shown in figure 6 showed consistent outcome as the outcome of Hubel and Wiesel's experiment shown in figure 1 where the tuned feature orientations (-45˚, 25˚) are evaluated.

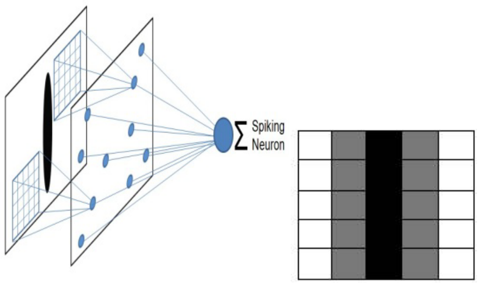

Figure 5. The artificial primary visual cortex model with orientation selective synaptic weights to mimick the simple cell.

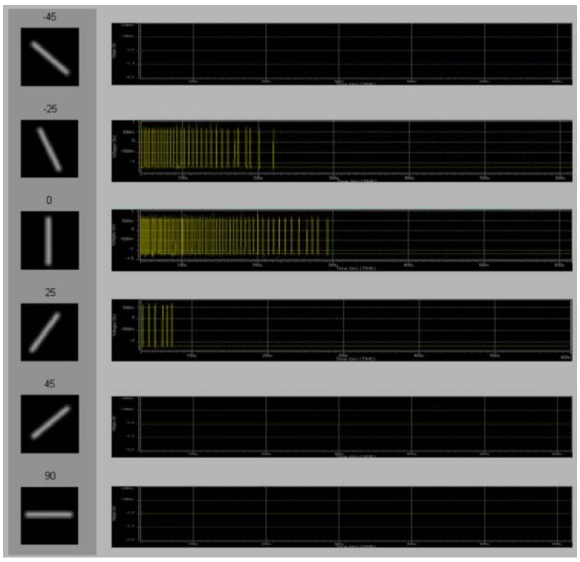

Figure 6. The simulated spike burst of VLSI visual cortex to stimulus in various orientations.

DETECTION OF PEDESTRIANS

Pedestrians are detected in two different environments; moving car and second floor of moving double decker bus.

For detection of pedestrians using bio-inspired approach, orientation features from the input image is extracted first. The number of different orientation angles to be extracted will be different depending on the type of the target to be extracted. For example, a vehicle or man-made objects tend to have lot of straight edges whereas a biological object such as pedestrian do not have much of pre-defined features so much more orientation feature extractors are used.

Figure 7 shows the result of detection of the cyclist from a video stream captured from inside the car using commercially available car black box. The orientation feature map shows much of background are extracted as well however after carrying out an neural network function the cyclist is detected at the end.

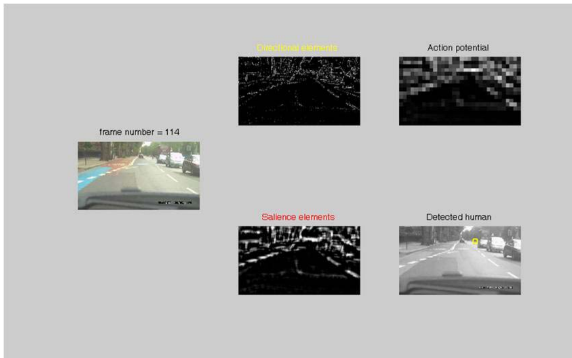

Figure 7. The detection of cyclist from input image from a car. (from right in clockwise direction) Input image, orientation feature image, action potential of neuron, detected image and salience image.

Detection of pedestrian from an image captured from the second deck of a typical bus in city of London is shown in figure 8. The video stream from the bus is quite different to the one captured from the car as shown in figure 7. Firstly, the angle at which the image is captured is different thus the effect of luminance level however the results show that the proposed idea is robust.

Figure 8. The input image captured from second deck of a bus in London.

The figure 9 shows the orientation features extracted from figure 8. From the initial orientation feature extracted, it is not easy to easily identify the pedestrian. But since video stream is being used, the difference of orientation feature reduces noise and outline of pedestrian can be more clearly seen.

Figure 9. Orientation features extracted from figure 8.

Figure 10. Difference of orientation feature map extracted from figure 8 and previous frame. Note that pedestrian is more clearly visible.

The difference image is then passed through a neural network which uses template of upper torso of human. The action potential of the resulting neural network shows strong signal from the pedestrian and figure 12 shows the successful detection of the pedestrian in the image.

Cyclist on the road can be just as dangerous as the pedestrian so the proposed idea is tested with a motorcyclist as shown in figure 13. The orientation features extracted, shown in figure 14, from this figure shows much of the image is extracted so that the motorcyclist is not so clearly seen. The orientation features of previous frame is used to difference the image as seen in figure 15, the motorcyclist is still not clearly seen as it did in figure 10. However when the neural network shown in figure 16 is applied most of the noise is diminished since the most of the background noise detected are from man-made objects such as vehicles or road signs and the template of the neural network is such that only the human-like objects are left. Then the resulting action potential shows clearly the motorcyclist and as expected the detection was successful as shown in figure 17.

Figure 11. The top image shows the result after neural network is applied to figure 10. Then (bottom image) shows the action potential of the neural network.

Figure 12. Successful detection of the pedestrian.

Figure 13. Captured image of motorcyclist from the second deck of a bus in London.

Figure 14. Orientation features extracted from figure 13. There is much noise extracted as well.

Figure 15. Orientation feature difference of orientation extracted from figure 13 and previous frame. Note that the outline of the vehicle is still quite strong.

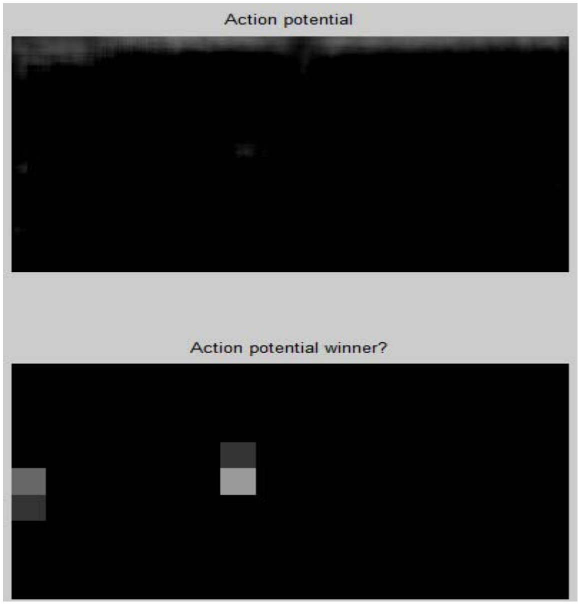

Figure 16. The result after neural network is applied. Note that after the neural network is applied much of noise is diminished and motorcyclist is detected clearly.

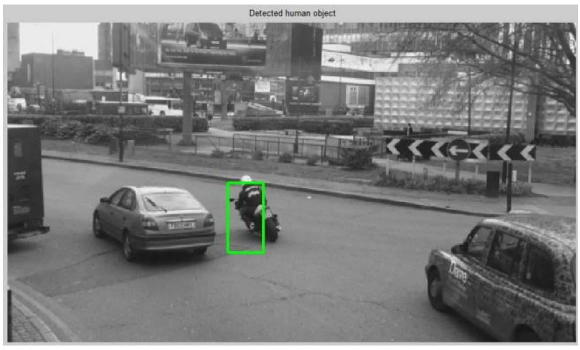

Figure 17. Successful detection of motorcyclist.

CONCLUSION

The bio-inspired approach to pedestrian detection was explored. The challenges of pedestrian detection are the quick changing of the environment and the condition so a robust algorithm is a must especially if such system were to be applied to actual vehicle as pedestrian detection system.

The detection of pedestrian and a cyclist taken from images captured from a car and a bus proved to be successful even if the conditions were different. Also the application of the proposed idea into a CMOS technology was explored as well with SPICE simulation of the idea.

ACKNOWLEDGEMENT

This research was funded by NRF, Korea. Grant No. 2010-0022245.

REFERENCES

[1] Yilmaz, A, Javed, O and Shah, M, “Object Tracking: A Survey”, ACM Computing Surveys, vol. 38, Article 13, 2006, pp.1-45.

[2] Hubel, D. H and Wiesel, T, “Receptive fields of single neurones in the cat’s striate cortex”, J. Physiol., 148, 1959, pp 574-591.

[3] Risenhuber, M and Poggio T, “Hierachical models of object recognition in cortex”, Nature Neuroscience, 1999, pp 1019-1025.

[4] Hausser, M, ”The Hodgkin-Huxley theory of action potential”, Nature neuroscience supplement, vol. 3, 2000, pp. 1165.

[5] Han, I. S, “Mixed-signal neuron-synapse implementation for large scale neural networks”, *Journal of Neurocomputing*, pp. 1860-1867, 2006.

[6] Han, W. J and Han, I. S, Bio-Inspired Visual Signal Processing based on Neuromorphic Circuit, in *Proc. WSEAS(IMCAS’10)*, (Hangzhou, 2010), pp. 131-136.