Computer Science Writing

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Literature Review

Introduction

This paper reviews two papers about spiking neural network applied in image processing. These two papers are in the subject of neurology and they also refer to segmentation and edge detection. Following, I give some brief introduction on neural network and image processing.

Artificial neural network is a mathematical model and computation model come from biological aspect of neural network. Neural network is constituted by artificial neurons which are used to process information by computation. Applications of modern neural networks are exploring complex relationship between input and output data by adjusting the response strength (weight) of each neuron to produce target signal. Due to the variety of possible inspiration from biological brain, artificial neural network has large diversity on its structure and computation method. "Therefore, there is no single formal definition of what an artificial neural network is."[1]

Normally, according to the differences between computation units, neural network can be classified into three generations [2]. The first generation neural network can process digital input and output information [2]. The second generation neural network, capable of handling analog signal, applied an activation function in neurons such as: $Y(x) = 1/1 + e^{-x}$, and typical representation of second generation neural network is feed forward and recurrent sigmoid network [2]. I review two papers about the third generation network which refers to spiking neural network. Spiking neural network is inspired by the fact that biological aspect of neural system encodes information by timing of action potential [2]. Specifically, neuron fire when it's potential reach threshold. Its potential is determined by presynaptic.

In the aspect of image processing, segmentation refers to divide image into several parts according to its properties so that this image can be simplified and easily to extract desired information from it.[3] It might also possible to change the representation of an image by segmentation[3]. Segmentation is usually applied to locate objects and boundaries[3]. Image after segmentation is covered by several areas which share similar color, illumination or texture. However, adjacent areas should have distinct differences with each other[3]. After segmentation, edge detection might be simpler.

"Edge detection is a fundamental tool in image processing and computer vision." [4] [5] Its main responsibilities are detecting and extracting features from images to capture important events. Discontinuities can be summarized as: "discontinuities in depth, discontinuities in surface orientation, changes in material properties and variations in scene illumination."[4] [5]

Review Papers

This literature focuses on two papers which refer to applying spiking neural network (SNN) in image processing. According to the abstract of [6], [6] depicts how to apply SNN to image segmentation and edge detection. In addition, it also proves the validity of the approach. What's more, abstract of [6] presents some contributions and features of SNN. Author believes that the third generation of neural network, SNN, is capable to handle problems regarding to biological stimuli, since SNN is inspired by synaptic interaction between neurons and it successful prevails the power of computation. SNN develops new horizons for building model and it adds new dimensions to capacity and processing ability of neural network. However, [7] gives more information regarding to the paper itself such as: what is purpose of applying SNN, structure and properties of SNN in [7], result of experiment and author's attitude towards the result, content of experiments and functionalities of SNN in [7]. Abstract of [7] is more informative.

[6] and [7] share the similar framework: introduction, information about SNN, experiment & result and conclusion. This literature review is developed based on structure of reviewed papers.

Introduction of [6] focuses on one point and the author contributes several literatures to support his viewpoint: while many methods have been put to computer-aided segmentation, artificial neural network has attracted tremendous attention, especially SNN which is more suitable for computer vision. 14 literatures have been summarized to persuade readers. Segmentation algorithms are based on threshold [8], clustering [9, 10], edge detection [11], region extraction [12], pattern recognition [13] or deformable models [14]. Author repeats some information in abstract that depicts the features of SNN. [6] Following, [6] gives several literatures on application of SNN. [15] applies hierarchical SNN to handle stimulus information. [16] segments grey-scale image by integrate-and-fire neurons. [17] applies leaky integrate-and-fire neurons to segment grey-scale image. [18] constructs a self-organized network[6]. It is obvious that proofs are sufficient, while the author fails to evaluate the result of application of these literatures and author does not address how these literatures contribute to his own work. In the end of introduction, [6] presents Hebbian based winner-take-all learning is applied and his network performs good. [7] presents a critical thinking in its introduction part and it also believe neurobiologists and computer scientists have paid large attention on visual cortex. SNN has been applied to stimulate various models of visual cortex[7]. However, author mentions the accurate neural circuit representation of visual cortex is still not clear[7]. Then, author talks about network constructed by Knoblauch and Plam [19], an oscillator network built up in [20] and another approach to recognize object by [21] to support several neural networks has been applied to show how visual system operate image [7]. Next, a more accurate model called RF-SLISSOM is presented. Author details some features of this model to show it explains some aspect of visual system. On the contrary, author mentions there is no evidence that can confirm this model but many experimental results support it [7]. Introduction of [7] gives critical think on why apply SNN to simulate visual system and make it acceptable. Both of [6] and [7] depict several literatures but only [7] describe the result of network and critical thinking is presented.

Both of [6] and [7] illustrate the structure of SNN. [6] states that SNN is more powerful than neurons calculated by sigmoid function. [22] Neurons generate spikes when internal state reach defined threshold. [6] The relationship between input spike and internal state is defined in [23]. Neurons usually have a set Γ_j of presynaptic and internal state of x_j is determined by [6]

$$x_j = \sum_{i \epsilon \Gamma_j} w_{ij} \varepsilon(t - t_i)$$

$\varepsilon(t)$ is the spike response function. [6] Author gives a positive evaluation to this function. The structure of SNN is depicted by Fig 1. Then author introduces structure describe in Fig 1(b). One individual neuron is constructed by several other "synaptic terminals" that have different delay and weight. [6] The internal state of this kind of "synaptic terminal" is defined by [6].

$$y_i^k(t) = \varepsilon(t - t_i - d^k)$$

d^k is the delay of k^{th} terminal. Combing previous two functions together, we have:

$$x_j(t) = \sum_{i \epsilon \Gamma_j} \sum_{k=1}^{all} w_{ij}^k y_i^k(t)$$

[6]. Both of how SNN works and architecture of SNN are clearly introduced.

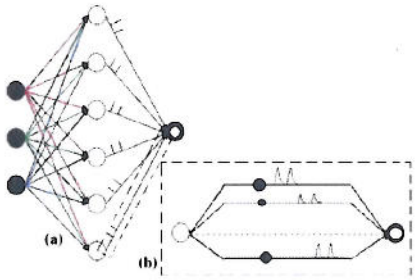

Fig 1. **(a)** SNN architecture and **(b)** multiple synapses transmitting multiple spikes [6]

Similar as [6], [7] details its SNN by formula and figure and you will figure out an entirely different structure shown in Fig 2. First [7] presents the inspiration of the structure that there are various receptive field in the cortex and "can be simulated by the Hodgkin and Huxley neuron model" [7].

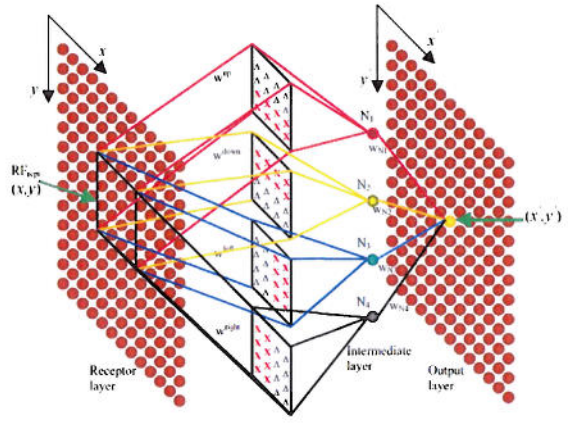

Fig 2. SNN architecture [7]

First layer refers to "photonic receptors" and each point stands for receptor regarding to one pixel. The intermediate layer is constructed by four kinds of receptive field. "X" stands for excitatory synapse. "Δ" stands for inhibitory synapse. Output neurons are determined by four outputs from intermediate neurons. Following, author states that integrate-and-fire model is similar to the Hodgkin and Huxley neuron model [15] and introduces several formulas to detail how this model works. In the end, [7] presents the mechanism to plot result figure by SNN. All in all, description of [6] and [7] is explicit.

Comparing to [7], [6] also provide additional information toward representation and training. Three different coding schemes are presented and author gives comments on these three coding mechanisms. In rate coding, information is contained in firing rate of neurons but robust to "ISI" noise [6]. "Temporal coding regards to temporal precision in the response that relates to properties of the stimulus" and it is difficult to identify a temporal code under the interaction between stimulus and "encoding dynamics" [7]. Collective activities of neurons are applied to represent information in population coding. [7] Author states experimental result shows widely application of population coding in the sensor and motor area in the brain. However, regarding to population coding, no evidence shows that the author's believe is confirmed.

In the end of second section, author presents some disadvantage of time encoding and details the mechanism of population coding by two formulas and one graph. However, author doesn't give any conclusion on these two mechanisms. Next, author talks about winner-take-all algorithm that applied to his SNN. This algorithm is clearly introduced by formula and a figure that shows learning function. Author also emphasizes some features of this system. Finally, author depicts the function of three layers of neural network applied to following experiments. Structure is similar to Fig 1(a), presented in Fig 3. Three neurons in input layer stand for RGB pixels. This network is fully connected feed-forward network. [6] Author gives comments on the design of structure and presents merits of the design.

Introduction of [6] is more comprehensive than in [7]. This makes reader easier to grasp the idea to do segmentation through SNN.

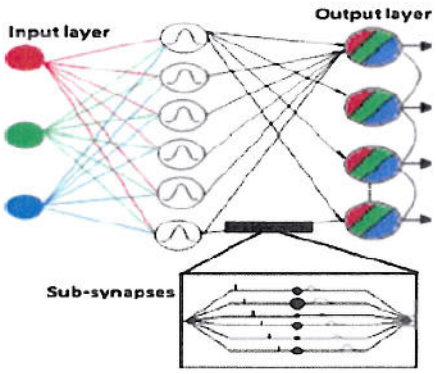

Fig 3. Network Topology

Regarding to the experimental part of this two papers, [6] develops a much more comprehensive test to verify the contribution of several parameters to whole network. Comparing to [6], [7] shows the result of segmentation and gives prominence to the features of [7]'s network. [6] borrows a technique from [24] to construct it own experiments. The target image is shown in Fig 4 (a). Author design several experiments to present the

influence of each parameter, such as: number of sub-synapses, number of receptive field, number of neurons at exit, the percentage of simple training and the learning parameter c. In addition, author also introduces an experiment to compare the result of SNN with other methods. [6] pays much attention to the experimental technique. Author keeps other parameters stable and only varies one coefficient to demonstrate the influence of this variable. What's more, author assesses the performance of SNN according to MSE, MAE, PSNR, NCD. However, author does not explain these terms before they are applied. Most importantly, these coefficients measure the difference between original image and segmented image. What is the relationship between error and segmentation performance? This part is confusing. Next, [6] apply SNN to another image to do edge detection and compare the result with other methods. Unfortunately, author just puts four images together without any analysis or techniques to evaluate the result. In [7], author first introduces the parameter setting of SNN and then presents the result image of edge detection with several words to explain the meaning of this result figure (original image shown in Fig 4(b)). Importantly, author conclude that it takes 50 seconds to get a fire-rate map for an 500*800 pixels image by a PC with 1.2GHz CPU. Furthermore, if this SNN is implemented on hardware then the time consumption can be reduced to 100ms which is consistent with visual system. This makes the SNN much more valuable. [7] fails to give any comment on the edge detection performance comparison between different methods neither.

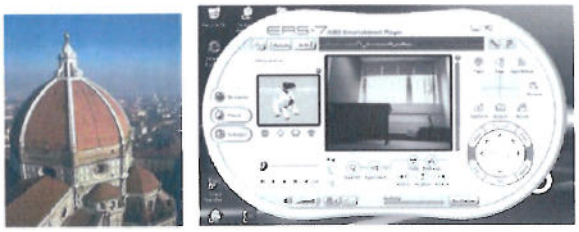

Fig 4. (a) Original Image from [6] (b) Original Image from [7]

Conclusion

[6] and [7] are focus on applying SNN to edge segmentation but through different approach since there are different ways inspired from biological aspect of human visual system. [7] provides a much more informative abstract than [6]. [6] introduces many evident and method from literature but only assesses few of them. This makes [6] looks like summarize sufficient literature but failed to build relationship between others' work with own. SNN of [6] is based on winner-take-all learning from Hebbian. [7] is based on Hodgkin and Huxley neuron model. These two papers all present their SNN mechanism clearly. Comparing to [7], [6] gives more comprehensive introduction to SNN, like coding schemes but [6] doesn't introduce which coding schemes it applies. Regarding to experiment of these papers, [6] has evaluate the influence of each parameter to the performance of SNN but fails to assess the performance of its SNN for edge segmentation. However, [7] explicitly demonstrates the performance of SNN by time consumption and mentions that SNN can be consistent with human visual system under hard ware. Further work should be focus on decreasing the time consumption while maintain similar edge detection result.

Report comprises 2068 words as counted with Office Word 2007, excluding the bibliography.

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