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Review

Pulse coupled neural networks and its applications

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ABSTRACT

This paper surveys the extensive usage of pulse coupled neural networks. The visual cortex system of mammalians was the backbone for the development of pulse coupled neural network. PCNN (Pulse Coupled Neural Networks) is unique from other techniques due to its synchronous pulsed output, adjustable threshold and controllable parameters. is Hence the uniqueness of this network utilized in the fields of image processing. The basic model of PCNN and the consecutive changes implemented, to strengthen the pulse coupled neural network are discussed initially. Then the applications of PCNN are broadly discussed. The other miscellaneous applications utilizing pulse coupled neural networks are thrown light in the last section.

1. Introduction

Image processing is a common term that covers image segmentation, image registration, image fusion, image thinning, image enhancement, edge detection, feature extraction, image recognition, noise removal from image, classification of images, texture and fabric defects identification, and surveillance. For all these above mentioned image processing techniques pulse coupled neural network was found to be a suitable processor. The applications of PCNN[2] are taken into consideration for a detailed survey. This network is very much finding its usefulness in diagnosis of diseases through image processing techniques. A few other applications other than medicine are also discussed to learn the extensive application of pulse coupled neural network. People find less time in analyzing and interpreting solutions for problems detected. Hence they seek the help from machines. Machines are thus trained to perform the functions of a human brain. The human brain contains about 10 billon neurons and those neurons are the participants in the parallel information processing system. Artificial neural networks were developed to bring computers a bit closer to the brain's capabilities.

Biological systems have always been an inspiration for developing algorithms. The mammal's visual cortex formed the base of some network models. Cat's and guinea pig's visual cortex helped in developing some digital models. The input information is received by the eye. Receptors within the eye (retina) are not sensitive to all the information. The sensitivity is based on color, motion and intensity. The receptor after receiving the information alters the behavior of surrounding receptors with respect to the contents and then forwards to the visual cortex and then the received information is analyzed by the brain. The functioning of the visual cortex has to be studied in order to develop algorithms. This is more complicated than programming of computers. Researchers started working in the beginning of 1950s (Hodgkin & Huxley, 1952). They had described the membrane potentials in terms of rate of change of different chemical elements. In the early 1960s, a mathematical model was developed by Fitzhugh (1961) based on coupled oscillators. The dynamics of neurons were in oscillatory process. They described the neuron as a two coupled oscillator that are connected to neighboring neurons. Later in 1990s Arndt, Dicke, Eckhorn, and Reitboeck (1990) introduced a model on cat's visual cortex. In their model, each neuron received input from its own stimulus and also from the neighboring neurons. The outputs from other neurons were also an input for the parent neuron. In 1992, Rybak, Sandler, and Shevtsova (1992) came up with a model based on guinea pigs'visual cortex. The model was similar to Eckhorn except in equations. Then Johnson and Ritter (1993) implemented the pulse coupled neural network and suggested a new mechanism with limited connectivity for information transmission. Also the network was implemented for image processing by eminent researchers (Johnson, Kuntimad, & Ranganath, 1995; Johnson & Padgett,

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[2] *Abbreviations used:* PCNN, pulse coupled neural networks; ICM, intersecting cortical model; fMRI, functional magnetic resonance imaging; EM-PCNN, expected maximization-pulse coupled neural network; BCFCM, bias corrected fuzzy c-means; IAF, integrate and fire; m-PCNN, multichannel-pulse coupled neural network; LSWT, lifting stationary wavelet transform; DWT, discrete wavelet transform; LSWT-PCNN, lifting stationary wavelet transform- pulse coupled neural network; NSCT, non-sampled contourlet transform; PCNNAI, pulse coupled neural network with anisotropic interconnections; FCM, fuzzy-c-means; PCNN-FMI, pulse coupled neural network-fuzzy mutual information; ADATE, automatic design of algorithms through evolution; FSD, filter subtract decimate.

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1999a, 1999b). An alternative model was suggested by Combe, Ducom, and Parodi (1996) in which delays were included in synaptic connections. Based on the above mentioned ideologies, the original pulse coupled neural network (PCNN) was developed and the simplified version of PCNN was intersecting cortical model (ICM) (Kinser & Ekblad, 2004; Kinser & Lindblad, 2005). Kilic and Kayacan (2012), Kinser, Atmer, Zetterlund, and Ekblad (2004) and the network is being utilized in many image processing techniques like feature extraction, image recognition and image segmentation (Li, Li, Xin, & Zou, 2011; Li, Wang, Wang, & Huang, 2010; Mahgoub, Ebeid, El-Badawy, & Abdel-Baky, 2008; Niu & Shen, 2009; Xu, Ma, & Zhang, 2008; Xu & Zang, 2008).

Pulse coupled neural networks are unsupervised networks, in which the network is provided with inputs but not the desired outputs. The network is self organized. Through this survey, the scope of PCNN in medical field as well as in the technical field is discussed with references from researchers and scientists.

2. Pulse coupled neural networks

PCNN is a self-organizing network that does not require training and the network was constructed by simulating the activities of the mammal's visual cortex neurons and the basic structure of the PCNN model is shown in Fig. 1.

PCNN produces an output of binary pulse images when stimulated with images. Johnson and Padgett (1999a,b) had enumerated the origin of PCNN, basic model and the relation to biological models in their wide research on PCNN. The biological compartmental model is shown in Fig. 2. The equivalent circuit of the respective model is shown in Fig. 3.

$Y(t)$ represents the pulse generator; E_m is the resting potential inside the cell (-70 mV); E_S is the synaptic back potential (+20 mV); C_1, C_2 are the compartmental capacitances (order of nanoFarads); g_{m1}, g_{m2} are the membrane intrinsic leakage conductances; g_{12} is the longitudinal conductance; V_1 and V_2 are the compartmental voltages;

The functioning of PCNN which is based on biological model is illustrated below. The number of neurons in the network is equal to the number of input images. Each pixel in the image is connected to a unique neuron and each neuron is connected with surrounding neurons through a radius of linking field.

The pulse coupled neural network has three compartments:

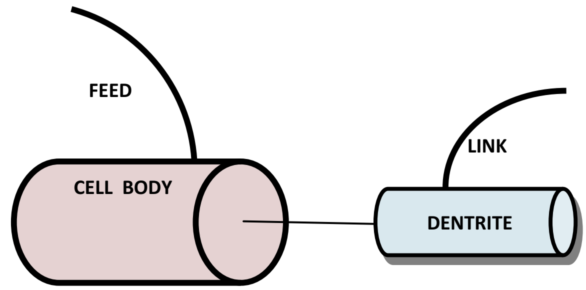

Fig. 2. Biological compartmental model.

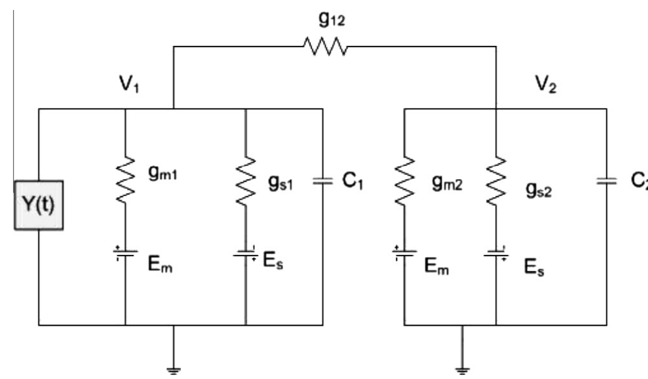

Fig. 3. Equivalent circuit of the compartmental model.

(1) receptive field,
(2) linking part or modulation,
(3) pulse generator.

Receptive field is the primary part to receive input signals from the neighboring neurons and from external sources and the field have two internal channels known as Feeding compartment F and linking compartment L. The linking inputs have faster characteristic response time constant when compared to feeding connections.

The biased and multiplied linking inputs are multiplied with the feeding input to produce the total internal activity U which constitutes the Linking or Modulation part.

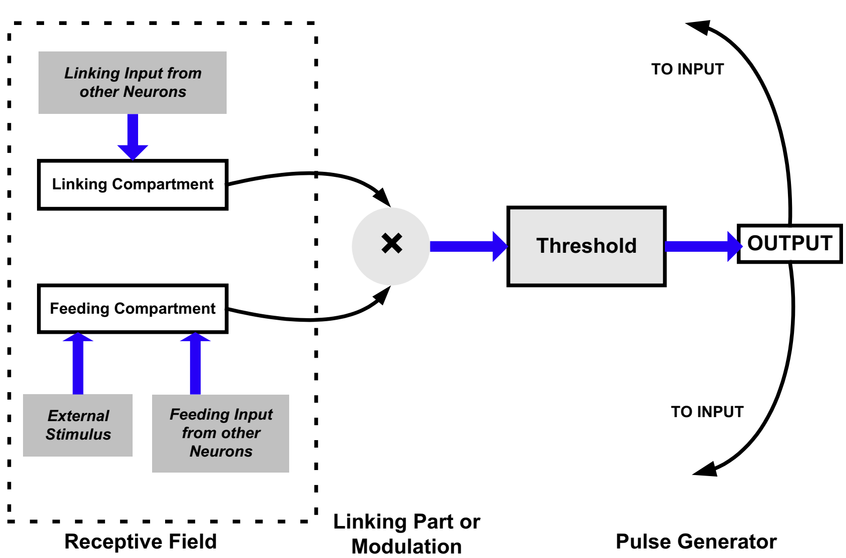

Fig. 1. Basic structure of PCNN neuron.