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Image Processing Applications of Pulse Coupled Neural Networks

Mugunthan S R

Associate Professor, Department of Computer Science and Engineering, Sri Indu College of Engineering and Technology, Hyderabad, India

E-mail: srmugunth@gmail.com

Abstract

The Pulse Coupled Neural Network (PCNN) is a neural network model that, when stimulated with a grayscale or colour image, generates binary pulse image collection. PCNN differs from other methods in several ways. It is unique due to its synchronous pulsed output, movable threshold, and programmable parameters. This research work reviews the current developments of PCNN and its applications in medical image processing domain. This study discusses the pulse coupled neural networks along with its application in various fields. Then, a summary of some current issues is presented along with some ideas to resolve it.

Keywords: Pulse Coupled Neural Network (PCNN), Medical Image processing, Neural Networks

1. Introduction

Image processing is a technique for applying different procedures to an image in order to extract some relevant information from it or to improve it. Image processing techniques are now used for a wide range of tasks in a number of different industries due to their increasing popularity. Within the fields of engineering and computer science, it serves as a core research area as well.

In general, image processing refers to the manipulation of a two-dimensional image, and digital images are considered to be two-dimensional. The use of a digital computer to manipulate digital image using an algorithm is known as digital image processing. When employing digital technique, all forms of data must go through the general phases such as pre-processing, augmentation, and presentation, and information extraction. A model of the cortex

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is used for several image processing applications since developing powerful image processing engines needs the usage of more powerful engines. Pulse Coupled Neural Network (PCNN) a popular image processing programme, is one of the applications. For many years, PCNN has served as the industry standard.

2. Pulse Coupled Neural Networks

PCNNs are the neural models that develop the high performance image processing by simulating the visual cortex of a cat. Eckhorn developed a neural model to imitate the workings of the cat visual cortex in 1989. The Eckhorn model gave researchers a quick and efficient way to examine the visual cortex of small mammals, and it quickly became clear that it could be used in image processing.

PCNN is a neural network method that, when stimulated with a grayscale or colour image, generates binary pulse image collection. The output of the PCNN's image processing capabilities was invariant to images that were scaled, rotated, shifted, and distorted. For many applications, pulse coupled neural networks have proven to be a very successful method. Picture processing applications using PCNN include object and edge detection, image fusion, image segmentation, and enhancement. Figure 1 shows each neuron of the standard PCNN model structure.

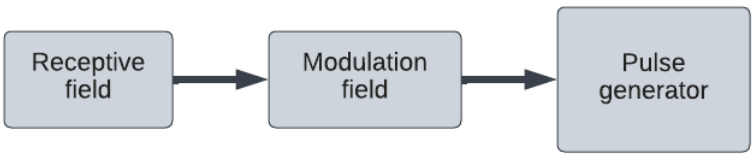

Figure 1. Standard PCNN Model Structure

Each PCNN neuron has three components, such as:

- Receptive field
- Modulation field
- Pulse generator

The receptive field, also known as feeding compartment F and linking compartment L, has two internal channels that are used to accept input signals from other neurons and from

external sources. Comparatively speaking to feeding connections, the connecting inputs have a faster typical reaction time constant. The neuron's pulse generator is made up of a threshold signal generator and a step function generator. The network's neurons have the capacity to react to inputs. Fired is the term for this reaction. When the neuron's intrinsic activity rises above a particular threshold, firing is enabled.

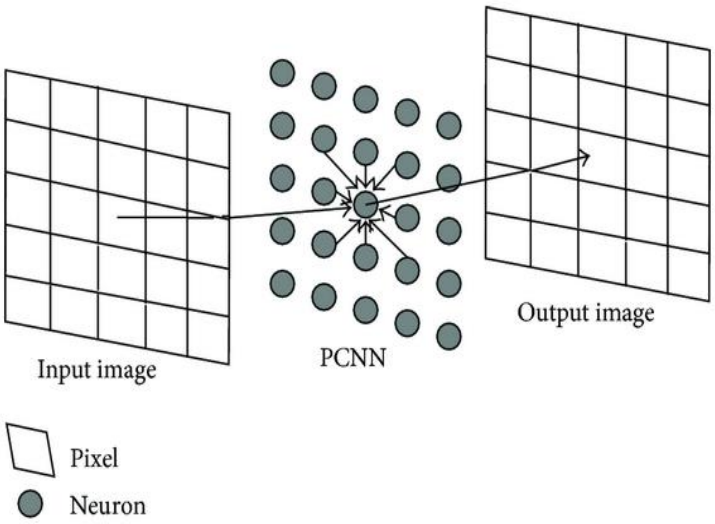

Figure 2. PCNN neuron connection model [11]

Figure 2 shows the connection model of PCNN neuron. In image fusion, PCNN is used to a single layer and two dimensentional array of pulse coupled neurons that are laterally linked. All neurons are the same. The number of pixels in the input image is equal to the number of neurons in the network. Each neuron is linked to nearby neurons within its connecting range. Adjacent neurons will get pulse output. Due to pulse linked action, nearby neurons that share the same intensity as the present neuron will fire simultaneously. In this instance, the neuron is recalled in order to record the nearby neurons. Finally, synchronous pulses will be released by the neuron and its related neighbouring neurons. As a result, PCNN possesses the global coupling and pulse synchronisation properties that are advantageous for image fusion since they utilize local image information.

3. Related Works

Ye et al., [1] discussed the Chaotic PCNN and Arnold Transform based on the Image Encryption algorithm which helps to improve the security and provide the better encryption result. The proposed approach provided more encryption effect than the existing algorithm.

Naik et al., [2] introduced the PCNN and Discrete Wavelet Transform techniques based on the image fusion that can be used to combine with any complex fusion operators and fusion rules based on wavelet decomposition. These results demonstrates how well the suggested technique works in preserving perceptually significant image information.

Tang et al., [3] explained the scale estimation method and image rotation estimation based on the PCNN and Gabor filter, which helps to improve the accuracy. The proposed method provided a more stable performance.

Peng et al., [4] proposed the Powder bed fusion based on the multi sensor image fusion method which is used to improve the image contrast. It also improved the display of the image edge contour.

Fan et al., [5] reviewed the Taguchi method (TPSCA) based on the PCNN, which increased the accuracy. The proposed approach enhanced the metaheuristic algorithm and sped up the computation.

Wan et al., [6] suggested the Multi-scale decomposition-based multi-focus image fusion technique of complementary information, which helps to provide more objective evaluation. The results of the experiment show that the suggested method can be more accurate.

Li et al., [7] described the PCNN and GIF-WSEML based on multimodal medical image fusion algorithm which contributes to improve the brightness and contrast in multimodal medical imaging, which results in higher performance. According on the experimental result, the proposed method takes more time than the existing methods.

Li et al., [8] analysed the Multispectral Image Fusion based on the Pansharpening PCNN model which provided better performance. This proposed approach provided the solution to overcome which also shows the proposed model's applicability for pansharpening.

Niepceron et al., [9] explained the Brain Tumor Detection System based on the Multi-Channel PCNN based Medical Image Fusion which is used to increase the accuracy. The experimental result shows that the computational cost and detection accuracy are good.

Table 1 shows the comparison of different techniques in PCNN used in various applications.

Table 1. Literature review

Reference	Proposed Techniques	Application	Dataset	Outcome
Ye et al. [1]	Chaotic Pulse-Coupled Neural Network and Arnold Transform	Image Encryption Algorithm	1.Lena 2.Cameraman	1. High Security 2. Better Encryption Effect 3.NPCR a. Lena image - 99.6460 b. Cameraman image- 99.5880
Naik et al. [2]	PCNN and Discrete Wavelet Transform techniques	Image Fusion	Self-made image	1.Muliti focus picture 2. Area of fusion picture 386
Tang et al. [3]	PCNN and Gabor filter	1.Image rotation estimation 2.Scale estimation method	1.Lena 2.Cameraman 3.House	1.High accuracy 2.More stable performance 3.Large Rotation estimation a) Lena - 0.0370 b) Cameraman- 0.0240 c) House - 0.0020
Peng et al. [4]	FDST, MSSTO, and PCNN-based multi sensor image fusion technique	Powder bed fusion	1.LP algorithm 2.RP algorithm 3.PCA algorithm 4. DT-CWT algorithm 5. PCNN algorithm	1.Improved image contrast 2. Increase the display of image edge contour 3. Average improvement rates of the FMP method a) LP- 3.944%, b) RP-8.542%, c) PCA-2.013%, d) DT-CWT - 1.738%, e) PCNN- 13.271%

Fan et al. [5]	PCNN	Taguchi method (TPSCA)	1.Image 1 2.Image 2 3.Image 3	1.Improve the accuracy 2.More efficient 3. Accuracy rate a) Image 1 -88.55% b) Image 2 -95.83% c) Image 3 -85.13%
Wan et al. [6]	Multi-Focus Image Fusion method and PA-PCNN	Multi-Scale Decomposition	1.Wine 2.Newspaper 3.Temple	1.Better objective evaluation 2.Objective Analysis $Q_{AB/F}$ a) Wine - 0.7162 b) Newspaper - 0.6751 c) Temple - 0.7642
Li et al. [7]	PCNN and WSEML	Multimodal Medical Image Fusion	CT and MRI images (Image fusion, Harvard)	1.Better Performance 2.High time consuming 3.Reduces the operation time 4.Average objective analysis a) VIFF- 0.5484 b) Q_W - 0.8968 c) API- 43.7113
Li et al. [8]	Pansharpening PCNN	Multispectral Image Fusion	1. Washington 2. Sichuan 3. Xinjiang	1.Better Performance 2.PPCN Q4 a) Washington-0.8884 b) Sichuan -0.8959 c) Xinjiang-0.9253
Niepceron et al. [9]	Multi-Channel PCNN based Medical Image Fusion	Brain Tumor Detection System	Brain MRI dataset	1.Increase the accuracy 2.Average IoU score of 0.78

Dey et al. [10]	Pulse Coupled Neural Network	Microwave imaging	MRI dataset	a) Decay constant 0.2 b) Linking strength 3

4. Application of PCNN

The PCNN's main application is image processing, and most research works focus on this field. A popular area of study in the science of artificial intelligence is PCNN. The network has numerous uses in many different fields, including medicine, research, surveillance, pattern recognition, etc. which are briefly described in this chapter. In order to analyse the potential future research topics and current trends in PCNN related image processing disciplines, the benefits displayed by the PCNN in these unique applications are examined.

4.1. PCNN-based image segmentation and image fusion

Perfect image segmentation can be achieved with the PCNN. The process of image segmentation divides pixels into regions, which establishes the boundaries of object regions. Segmentation utilizes the features that have been taken from the image. As a result, segmentation needs to use carefully chosen features.

In image processing, image fusion is a very important technique. In recent years, there has been a great deal of research into PCNN's use in the field of image fusion, namely in multi-focus image fusion and multimodal medical image fusion. This is due to PCNN's superior feature extraction capabilities.

4.2. Edge Detection and Feature Extraction using PCNN

Along with image segmentation, edge detection and feature extraction are the other areas where the PCNN is frequently used. The PCNN is typically used to extract an object's features. In order to extract image features, the authors changed the original PCNN into a Unit Linking Pulse Coupled Neural Network, incorporating the intensities (colour information) and geometric structures (colour distributions) of the images.

4.3. Medical imaging with PCNN

PCNNs which are suitable for image pre-processing, are being used by several researchers to develop image segmentation methods in the medical industry. Medical

applications and surveillance methods make the best use of image segmentation [12]. Results from medical image segmentation have a significant impact on the identification of diseases or inadequacies. PCNN is useful for identifying crop diseases.

4.4. Miscellaneous

Other image processing applications are introduced here, in contrast to the previously listed ones. Many research have been carried out and implemented utilising PCNN, which is a powerful resource. Data reduction in data mining is an important effort, and PCNN has effectively used the network for this purpose to improve classification and regression.

5. Discussion

PCNN's research status through the last ten years have been summarised in this study. Without a question, the PCNN has made remarkable progress. However, in order to advance forward, several issues that need to be addressed should also be mentioned.

The main advantages of PCNN in the field are:

1. The absence of a prerequisite training requirement
2. Excellent image segmentation and feature extraction capabilities
3. The capacity to analyse images at different resolution levels.

Some of the PCNN study's puzzles have not yet been fully solved are:

1. A method for choosing the parameters
2. The cost of the computation
3. Nonlinear mechanism
4. Adaptive parameters setting

6. Conclusion

Pulse Coupled Neural Networks (PCNNs) model real time-dependent neural activity. In this study, pulse coupled neural networks' most recent advancements and uses in image processing have been discussed. Moreover, the concept and definition of PCNNs are illustrated, stating its advantages and disadvantages. In each category, representative models and current

trends are summarised. Finally, some potential future study areas on the issues that still need to be resolved are highlighted. To conclude, PCNN models are evolving quickly, and it is anticipated that future use cases for these cutting-edge new models will increase. It is also projected that more research will be initiated in the near future.

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