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Cellular Neural Network, Fuzzy Cellular Neural Network and its applications

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Abstract: Cellular Neural Network is recognized as an powerful tool applied in pattern recognition, image processing, medical signal processing. And also used to analyze the balance of energy-accuracy in image enhancement. In this paper, it is divided in various sections i.e. briefly explanation of cellular neural network and fuzzy cellular neural networks is described in section-I. In section-II, Memristor based CNN is defined. Various applications of CNN to image processing, pattern recognition are illustrated in section-III. And some applications of FCNN are explained in section-IV. Finally, it is concluded in section-V.

Keywords: CNN, FCNN, Memristor, Image Processing, Pattern Recognition.

1. INTRODUCTION

Cellular Neural Network is the collections of interrelated cells connected to each other by the specified radius. It is a parallel programming concept which is equivalent to the nature of neural network. And it was firstly defined by Leon O. Chua and Lin Yang, Berkeley in 1988[1]. The CNN processors can be defined in 2D and 3D arrays of dynamical processing units called cells. The nature and behavior of cells are correlated by the parameters which are determine the connection pattern is known as Cloning Template. In CNN, every cells has it's a state, an input and an output which interacts with each other through the predefined radius.

$$\frac{dx_{ab}}{dt} = -x_{ab} + \sum_{(m,n) \in N(a,b)} A(a,b;m,n)y_{m,n} + \sum_{(m,n) \in N(a,b)} B(a,b;m,n)u_{a,b}$$

$$y_{a,b} = f(x_{a,b}) = \begin{cases} 1 & \text{for } x_{a,b} > 1 \\ x_{a,b} & \text{for } -1 \leq x_{a,b} \leq 1 \\ -1 & \text{for } x_{a,b} < -1 \end{cases}$$

The above equation represents the standard equation of CNN with the input ($u_{a,b}$), the state ($x_{a,b}$), the output ($y_{a,b}$) of the cell located at (a,b) [18].

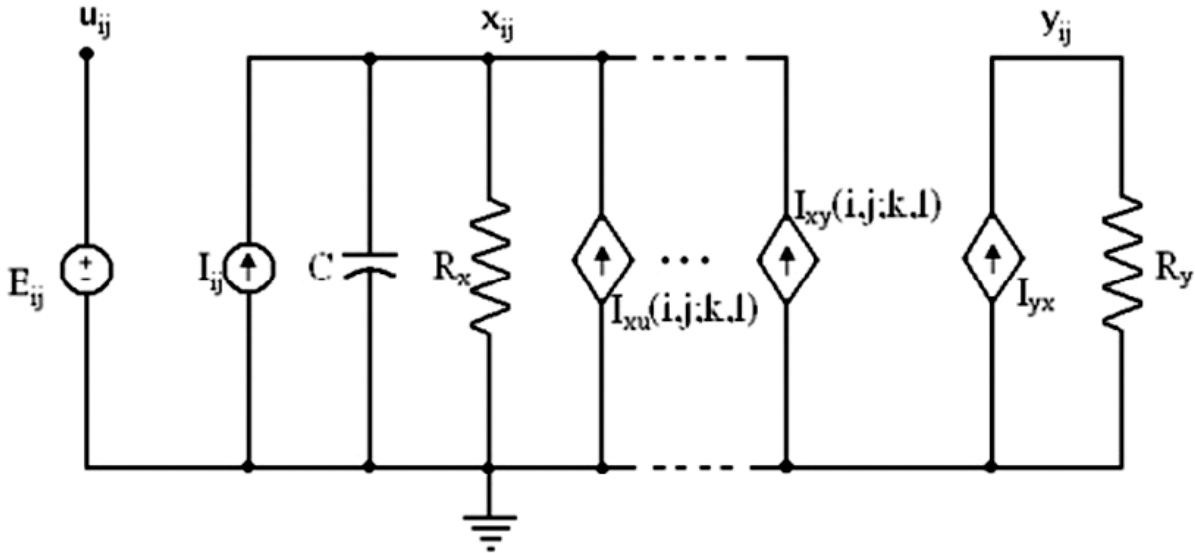


Figure 1: Representation of Cell Circuit [19].

The figure 1 and the equation both are same. The row and column are represented by (a, b) in the equation where as in diagram it is represented as (i, j).

The indices (m, n) represents the nearest cell which is neighborhood (N_{ab}) of the cell located at (a, b). The output of the cell is

$$y(a, b) = f(x(a, b)) = \frac{1}{2} [(x + 1) - (x - 1)]$$

Consider a two-dimensional CNN having dimension $[5 \times 5]$ in a array of rectangle of $r = 2$ neighbourhood. In case of digital CNN, a cell of 130nm CMOS was designed to analyze the energy accuracy tradeoff and their simulation was done by using SPICE for the estimation of power and BER for voltages and precision is used and reduced precision results better energy accuracy tradeoff than VOS (Voltage Over Scaling)[20].

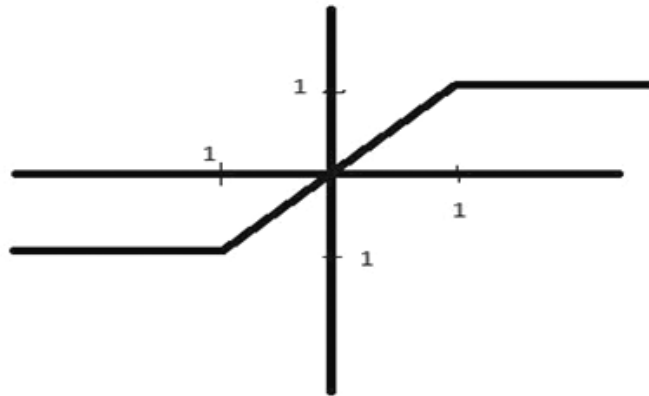


Figure 2:

The circles are called as cells which are interacted with each other. The Fuzzy Cellular Neural Network is nothing but it is equal to cellular neural network but in FCNN fuzzy operation is used according to their application.

The concept of Fuzzy set theory with cellular neural network will boost the application of image processing. Here Fuzzy AND and Fuzzy OR operators are used in synaptic weights among the cells. The biggest value and smallest values are mentioned in the templates.

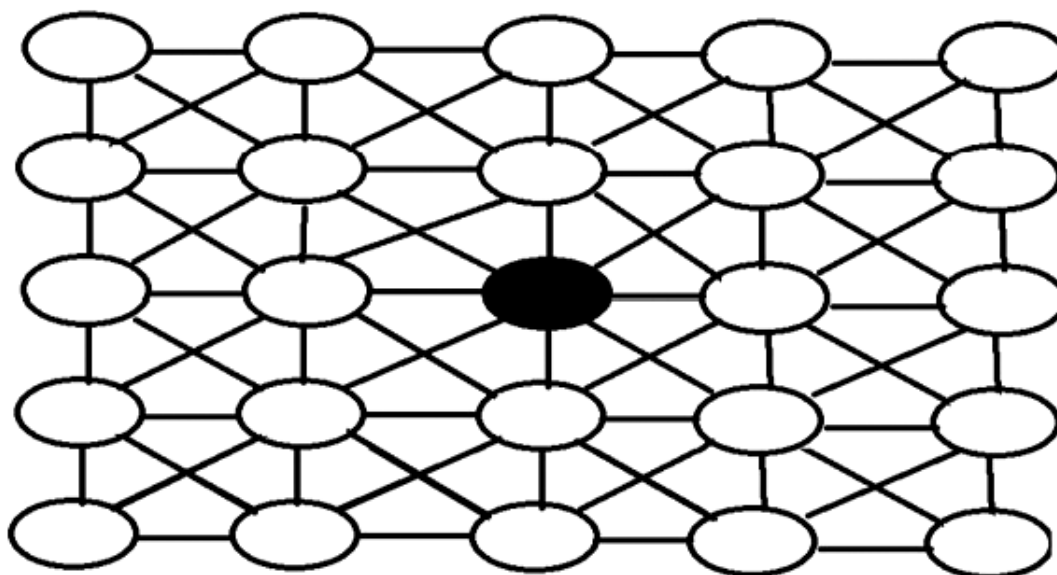


Figure 3: Represents as a two dimensional Cellular Neural Network.

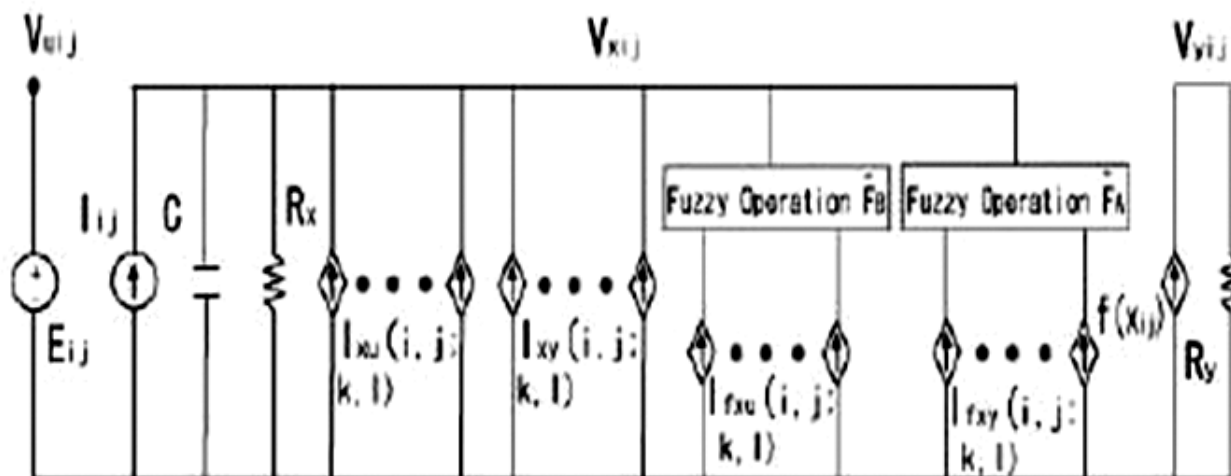


Figure 4: Represents the cellular neural network with fuzzy operation i.e. architecture of FCNN [15].

2. MEMRISTORS BASED CNN

Leon O. chua introduced memory with register which is called as memristors. The demand of memristors day by day increased due to huge applications in the area of neural network, image processing, and control engineering, programming codes and so on. In [3] for the measurement of cross bar device, one PCB measurement board with software is designed. One hybrid memory system is designed to reduce the energy consumption by the memory crossbar and also it is performed with the analysis and design of wired resistance [4]. By the biological point of view, memristors are also used in neural network. In the field of learning and forgetting, neurons are

connected through synapses for transformations of messages to one another. To integrate the operations of the neuron, CMOS technology is used [5]. Due to use of this technology, it provides strength to the neurons and also it consumes less amount of energy.

In [2], it is explained regarding the memristors with CNN as compare to traditional CNN. In MCNN, the storage capacity is increased due to associative memory with MCNN. Zhenyuan Guo et.al had represented theoretically regarding the invariance and attractively of the MCNN. And also in [6], details of mathematical analysis of MCNN is defined with replacement of register. And by using Lyapunov stability, it is minimized the decay of fault tolerance is illustrated. The memristor with cellular neural network is also implemented in electrical and biological field regarding the usefulness of synaptic weights. In [7], the synapse considered as a memristor crossbar circuits by which synaptic weights are managed smoothly.

In Mm CNN design, G^+ and G^- are used as a conductance with dual memristors. And memristor cross bar synapse is used as a synaptic weight where through the input voltage and memristor weight is managed. In [8], the read and write operations memristors are defined.

In [8], generally basic elements of electrical characteristics of memristor and design implementations are illustrated and investigated the analysis of read and write operations with regarding to the noise tolerance. In nano scale, Memristor is the most advancement tool and generally memristor is purely depends upon the voltage and current. Hence it is properly programmed and alternate current signals are provided so that the state of the memristors are maintained [9]. The multilayer CNN means each cell having multiple state variables with which it is robust as compare to the single layer CNN where it is most suitable to solve complex problems. In [10] RTD-M-CNN model is proposed by which is more beneficial to nonlinear current-voltage of the cell. After the

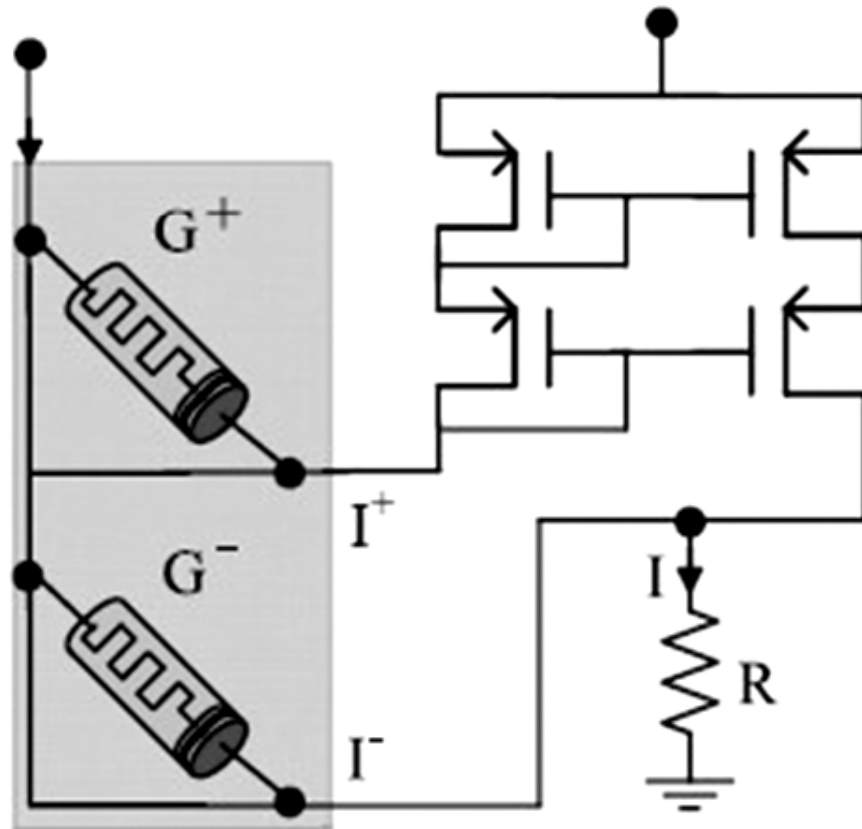


Figure 5: In [7] Graphical representation of memristor crossbar synapse.

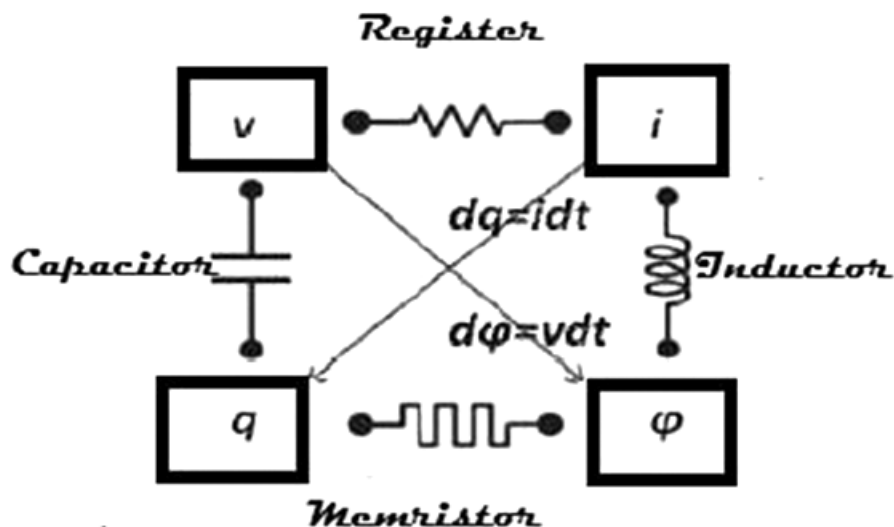


Figure 6: Represents the basic four elements of the circuit [8].

combinations of RTD types cell and synaptic circuits with memristor will improve the result of density and resolutions regarding the multi layer CNN.

3. CNN APPLICATIONS

Cellular Neural Network is nothing but it is the collections of parallel processors by which information are shared among them. In [11], shape from shading problem (SFS) is defined. SFS is defined as the formation of 3D shapes from 2D images by which it depends upon the surface shape and image brightness and also depends upon the algorithm for formation of 3D shape.

In Fig 7 and Fig 8 both represent the 3D shape from the input images are present nearest to the left in both the figures [11]. The algorithm implemented by the Mariofanna Milanova and et.al is very efficiently implemented as their output shows. And it is compared to the other literature which provides a new concept regarding to the parallelism. In [12], CNN-MVN and CNN-UBN is proposed and it shows the good results in image processing applications. The most important feature in this method is that the use of neurons in CNN which provides the reduction of noise, detection of edge and to solve complex problems. It is a very difficult task to determine fault free and fast edge detection in image analysis and pattern recognition. In [13], CNNUM

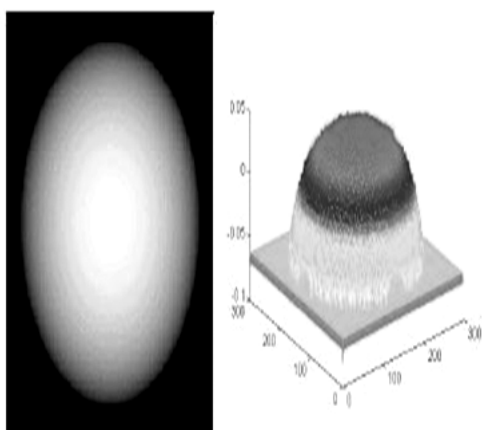


Figure 7: 3D Shape output by 2D input image [11]

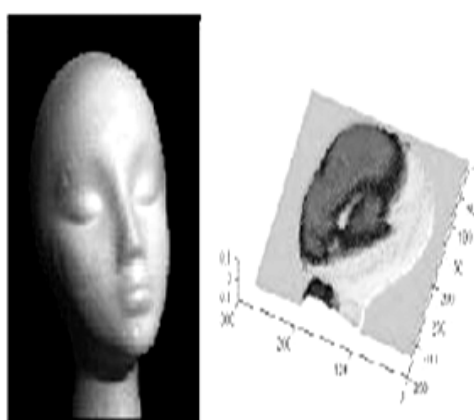


Figure 8: 3D Shape output by 2D input image [11]

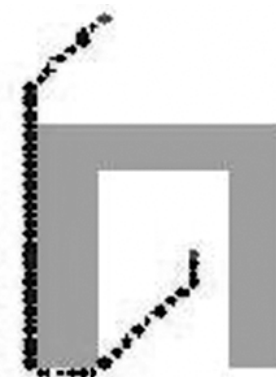
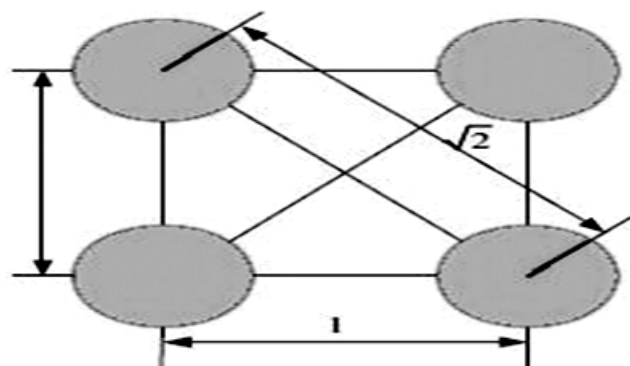


Figure 9: The weight of edge in the two dimensional [14] Figure 10: U-shaped motion planning in the environment [14]

(cellular neural network with universal machine) has adapted. By this approach, it provides the accurate results regarding the image processing applications. And it is also compared with Log edge detector and Canny algorithm to prove accurate result. In [14], the shortest path CNN is proposed with the comparison of CNN which is applied in motion planning. Generally motion planning concepts are defined in mobile robotics. In this method a novel CNN concept is implemented to detect the motion planning which is the difficult task in mobile robotics. Hence SP-CNN is used to solve the problem.

The above figures represent the after application SP-CNN in motion planning the maps changes suddenly. In Fig 9, $\sqrt{2}$ is the Euclidean distance between centre of the grids which are mentioned in Fig. 10. CNN processors are used in missile tracking, flash detections and diagnostics of spark plug(Microprocessor).In case of Biometric technology such as fingerprint recognition, for tracking the face CNN processors are used for better performance regarding the result.CNN processors are also used in medical and biological science for recognition of to calculate the nucleated cells to separate hyperplasia. Due to hyperplasia organs become enlarge and it may cause cancer. But due to use of CNN processors it will identify the measurement of cardiac function, neuron timings; disorder of brain which will prevents the seriousness or hazardous condition. In natural systems, to recognize the pattern generation, CNN processors are also used. In case of decision making and control system, CNN processors are also used for to get more efficient result in the system. Due to less power consumption, robustness of spectrum features, CNN processors are used in turbulent communications. In cryptography, for the secure communication more authentications is required; hence CNN processors are also used for authentication by the process of encryption and decryption method.

In case of neuroscience also CNN processors are used to design the knowledge and ideas of the system.CNN processors are used as a tool to recognize the nature which helps for analysis and to conduct experiments. In mathematical concepts CNN processors are also used to detail study of nonlinear and non equilibrium systems [18].In case of large images, CNN is applied for efficient results and for it programmable multiplexing algorithm is used. And for robust application, small hardware's are used and also defined micro architecture for real time applications to image processing [21].

4. FCNN APPLICATIONS

If we apply fuzzy logic to cellular neural network, it provides effectiveness of the result. In [15], three images are applied with FCNN i.e. fuzzy operations are applied for better results. and also by the applications of fuzzy operations into the CNN provides in non-linear synaptic ways. These synaptic forms provides robust to the image processing. In [16],a state estimator is implemented to estimate the neurons. By developing a novel Lyapunov- Krasovskii functional containing a triple summation term and by using LMI approach, it is guarantee that the no problems to the asymptotic state estimator. In [17], it is investigated that fuzzy cellular neural networks

with time- varying delays. by using the fixed point theorem and application of Lyapunov functional, global exponential stability of equilibrium point are illustrated. FCNN also used in uncertainties and modeling of neural systems and represents a interface layer between CNN and uncertainties. Advanced FCNN is used in medical science to recognize the CT of liver images which provides better results. Recurrent Fuzzy Cellular Neural Network (RFCNN) is the collections of nodes, each nodes are connected by weight functions. RFCNN has five layers, first layer defines one input statement, where as the second layer represents the membership function having fuzzy variables. In Layer three fuzzy rules with AND operation is implemented. And in fourth layer, it defines consequent layer which is also called as feedback layer. The fifth layer represents the output function which behaves like a defuzzifier [26].

5. CONCLUSIONS

In this paper, we had studied detail about cellular neural network with it various applications. And also briefly explained about use of memristor with CNN. And also studied various applications of CNN in biological science, neuroscience, for authenticity in security. The experimental applications of CNN and FCNN are defined in comparatively way which provides better understanding. The details about fuzzy cellular neural network also discussed and briefly explanation and its applications are given. In future some latest trends in cellular neural networks can be added to it. And also various applications regarding to the face recognition and pattern recognition in latest trends in engineering using CNN can be added for more effectiveness.

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