Cellular Neural Network

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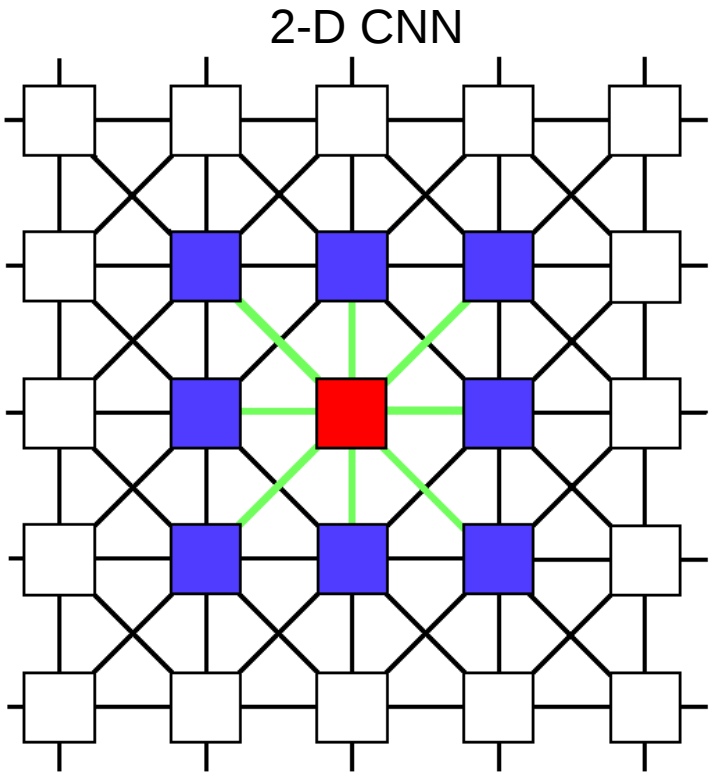
Introduction

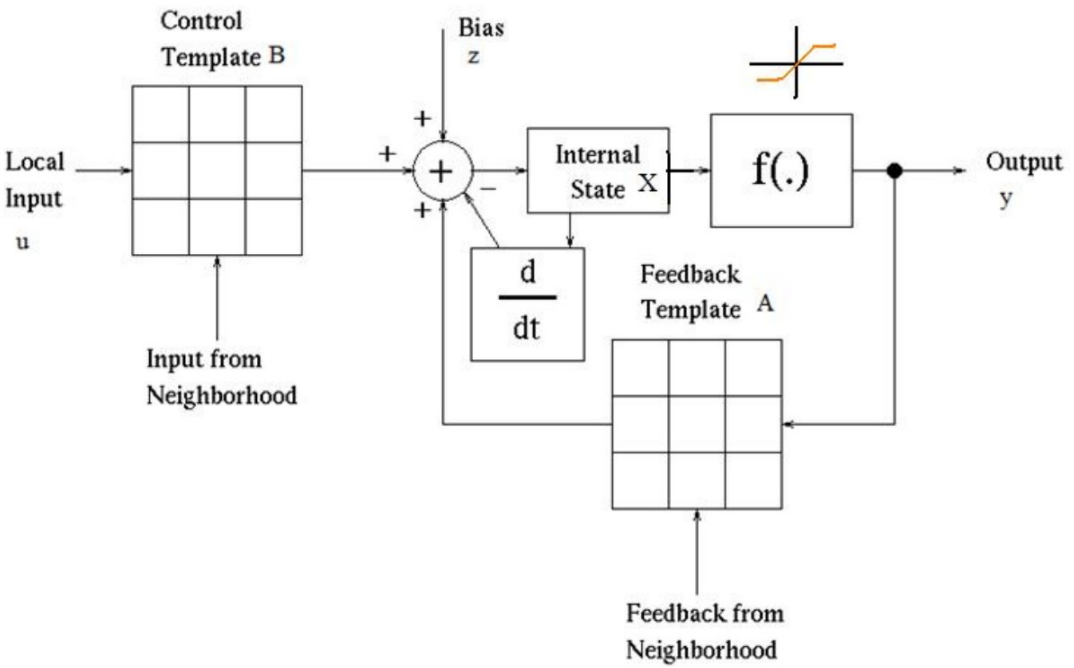
- Idea introduced by Leon O. Chua and Lin Yang in 1988
- Form of Analog computer
- Hybrid between Cellular Automata and Hopfield network
- Has more practical applications and well suited for VLSI implementation (localizaton)

Fundamental Ingredients of CNN

- N dimensional analogous processing cells - Topology
- Local interaction and state transitions - Dynamics



Dynamics of a CNN cell



State equation : $$\frac{dx_{ij}}{dt} = -x_{ij} + \sum_{\substack{C(k,l) \\ \in Sr(i,j)}} A(i,j;k,l)\, y_{kl} + \sum_{\substack{C(k,l) \\ \in Sr(i,j)}} B(i,j;k,l)\, u_{kl} + z_{ij}$$

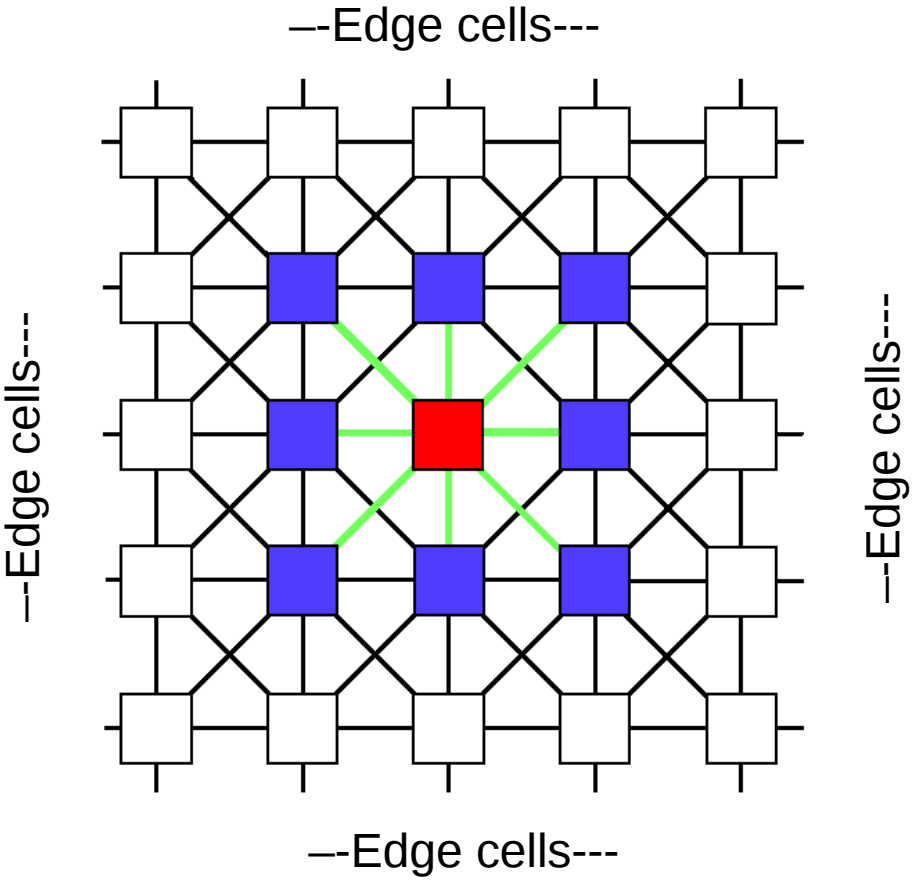
Output equation : $$y_{ij} = f(x_{ij}) = \frac{1}{2}\,|\,x_{ij}+1\,| - \frac{1}{2}\,|\,x_{ij}-1\,|$$

Dynamics (contd.)

- Sigmoidal/non-linear output function
- Explicitly parallel computing paradigm
- Suited for compute intensive problems expressed as function of space time. Ex: visual computing or image processing
- Emulate cellular automata, reaction-diffusion computing, neural network
- Also can construct boolean function so universal

Compute parameters of a CNN

- Control template
- Feedback template
- Bias
- Initial state
- Boundary conditions:
  - Drichlet (Fixed)
  - Zero flux (Neumann)
  - Periodic (Toroidal)



Factors that influence the compute parameters

- Space invariant
- Time invariant
- Sphere of influence
- Feedback:
  - Excitory vs Inhibitory feedback [A]
- Class:
  - Feedforward [A], autonomous [B] and Uncoupled variants [A]

[A] → Feedback Template

[B] → Control template

Design Motivation

Neuroscience confirms that CNN models the working principles of many sensory parts of the brain

- Continuous time continuous valued analog signal
- 2 dimensional strata of analog processing cells
- Integration of sensing and processing like in Biological visual system comprising retinal photo detectors and local neurons associated with them.

“Local interaction plays key role in some of the Global optimization problems”

Edge detection using CNN

- u(t) = Binary Image 100x100
- X(0) = 0
- Boundary conditions = 0, Z = -0.5, r = 3
- A

0	0	0
0	2	0
0	0	0

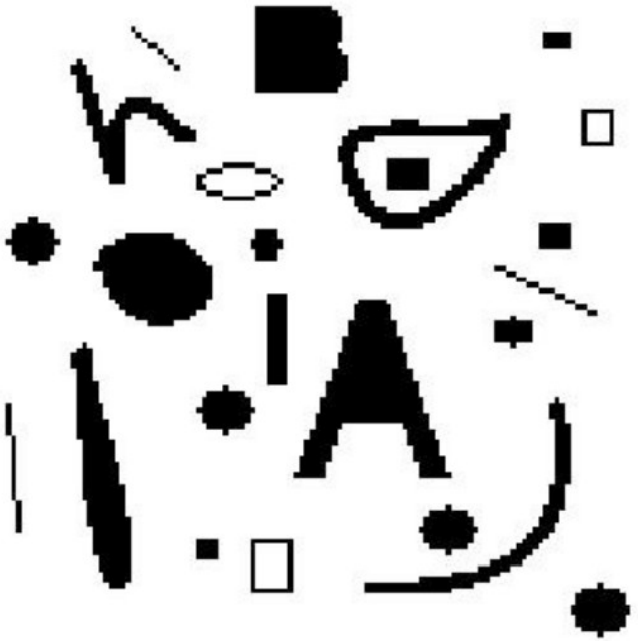
B

-1	-1	-1
-1	8	-1
-1	-1	-1

- Output, y(t) = Binary Image

Edge detection Output

Original



EdgeW

Binary Skeletonisation using CNN

- u(t) = Binary Image 100x100
- X(0) = 0
- Boundary conditions = 0, Z = -3.4 , r = 3
- A

0	0	0
0	1	0
0	0	0

B

1	1	1
0	7	0
-0.5	-1	-0.5

- Output, y(t) = Binary Image

Binary Skeletonisation Output

Original

After Skeletonising

How to select or design a template?

- Use the existing libraries and relevant research for common problems
- Use Training Techniques
  - Gradient decent
  - Backpropogation
  - Genetic Algorithms

    p = { $A_{11,}$ A_{12}, ……, A_{33},B_{11},B_{12},……,B_{33}, Z}

    19 real numbers.
  - Based on existing research, backpropogation is fast but genetic algorithm provides best result in the presence of noise

Implementation

- Currently available as semiconductors
  - Analog CNN processors
  - Digital CNN processors
- First “Algorithmically Programmable Analog 8x8 CNN” was created in 1993 with programmable selection templates
- Digital CNN is mainly implemented on FPGA, are flexible, easily programmable but Analog counterparts are Fast !!
- In 2006, *AnaLogic Computers* developed Bi-I high speed smart camera with ACE 4K CNN processor

Applications

Can process frames at > 10,000 frames/s and can go upto 50,000 frames/s

- Image processing and feature extraction
- Flame analysis
- Sensor actuator network
- Stochastic simulation, seismic wave propogation

References

- https://en.wikipedia.org/wiki/Cellular_neural_network
- Cellular Neural Network and Visual Computing, Leon O.Chua and Tamas Roska
- http://cs-wwwarchiv.cs.unibas.ch/lehre/hs09/cs302/resources/10c-CellularNeuralNetworksAndVisualComputing.pdf

Thank You
Questions ??