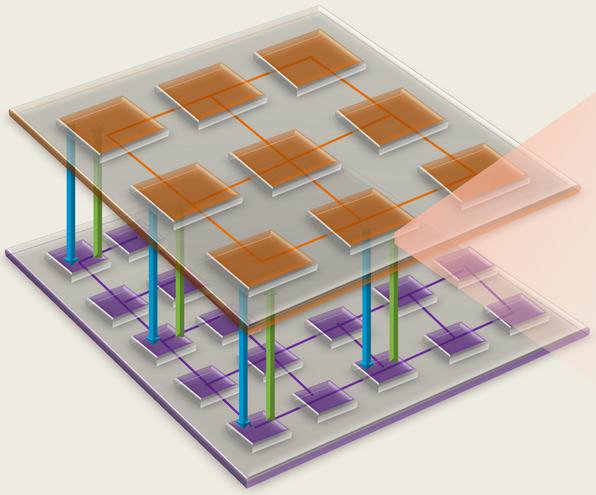
Emergent Intelligence in Cellular Neural Networks

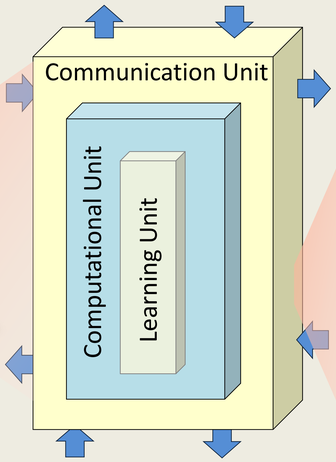
Bipul Luitel and G. Kumar Venayagamoorthy
iambipul@ieee.org, gkumar@ieee.org
Real-Time Power and Intelligent Systems (RTPIS) Lab., Holcombe Dept. of Electrical and Computer Engineering, Clemson University, Clemson, SC 29634

Decentralized Asynchronous Learning in Cellular Neural Networks [1]

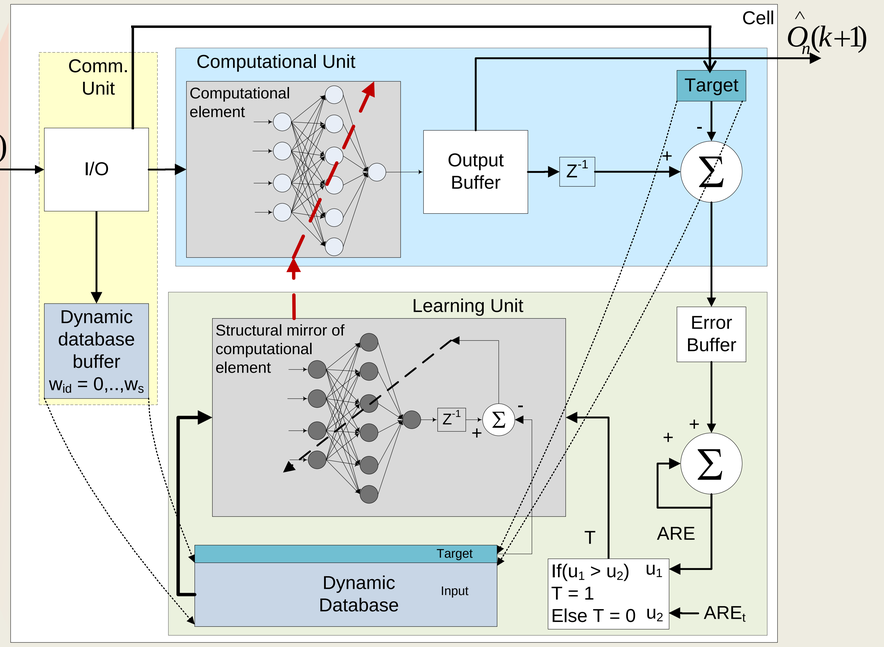
Cellular Neural Network (CNN)



A Generic Cell



CNN in Decentralized Asynchronous Learning (DAL) Framework



[1] Luitel B., Venayagamoorthy G.K., "Decentralized Asynchronous Learning In Cellular Neural Networks," IEEE Trans. On Neural Networks and Learning Systems, To Appear

Intelligence in CNN Emerges From A Group of Cells ..

Formation

Centralized | Decentralized

.. that may be either spatially collocated or distributed across a wide geographic area.

Structure: architecture and size

Homogeneous | Heterogeneous

.. that may either be identical in architecture and size or different from each other in their structure.

Implementation (Hardware/software)

Parallel | Sequential

.. that are either implemented sequentially or in parallel hardware and/or software platform.

Learning or adaptation

Learning Method
- Homogeneous
- Heterogeneous

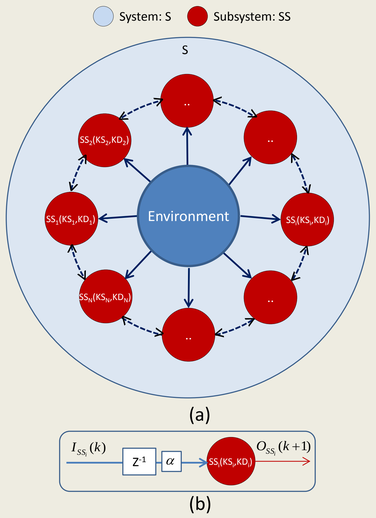
Adaptation
- Synchronous
- Asynchronous

.. that are learning subsystems, all of which either utilize the same or each of which utilizes a different learning method.

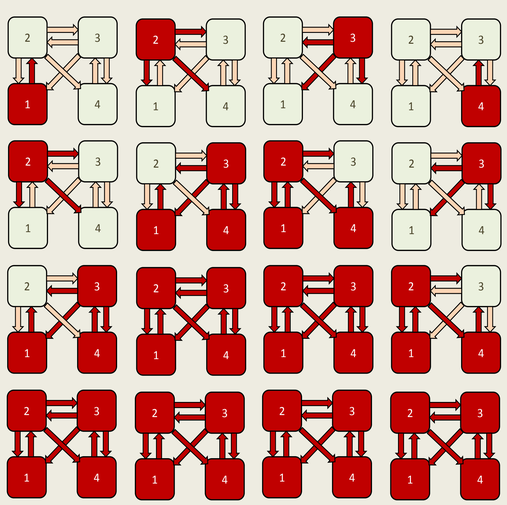
.. that either adapt themselves in synchrony with the other subsystems or independent of the others in their own pace.

Intelligence in CNN emerges over time through progressive learning and adaptation of these distributed interacting subsystems represented as cells.

Learning of Learning Systems



Knowledge Propagation in CNN

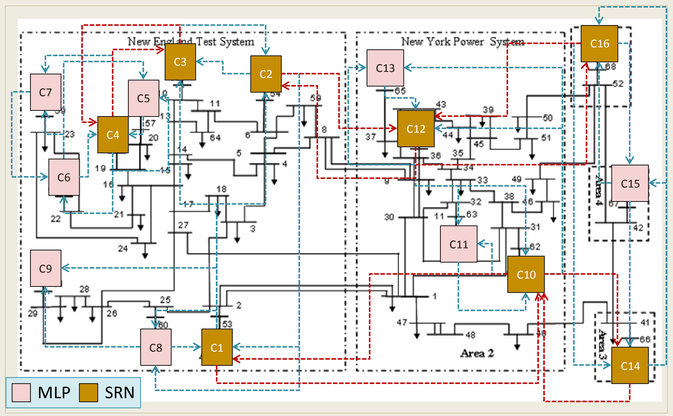


$$O_{SS_i}(k) = f\left(\alpha_i O_{SS_i}(k-1), \alpha_n^1 O_{SS_n^1}(k-1), \ldots, \alpha_n^N O_{SS_n^N}(k-1), KS_i, KD_i\right)$$

Learning of learning systems is a social behavior of swarms where each individual learns at different pace, at different times and in different environment while still interacting with the other individuals of the society. Learning in an artificial system having spatially distributed interacting individuals is known as learning of learning systems. In a decentralized asynchronous learning framework, learning takes place locally on spatially distributed cells that learn asynchronously. The cells collaborate to achieve learning of the overall system. Cognitive learning takes place when parameters directly affecting the cell change and the cell has to update itself to reflect the change. This new acquired knowledge is then transferred to the other members of the network (neighboring cells) through the communication unit. As a result, the neighbors observe a change in the behavior, and update themselves. The new knowledge acquired by one cell thus propagates through he network which results in social learning.

Application

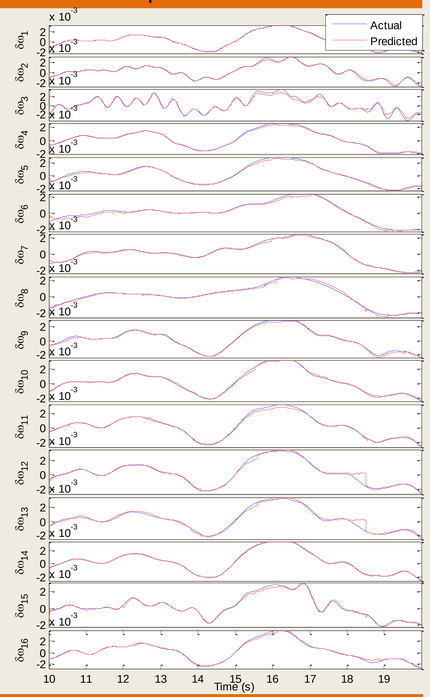
CNN Implementation of 16-generator 68-bus System



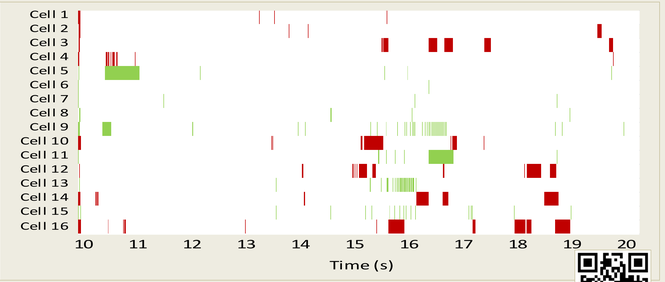
Results

Prediction of Generator Speed Deviation

Wide area monitoring system developed using CNN with DAL framework is able to predict speed deviation of 16 generators in a 16-generator, 68-bus system.
The CNN is developed using heterogeneous structure (different computational units in different cells) as well as learning method (some cells trained using backpropagation while others using particle swarm optimization algorithm. Threshold error for learning in each cell is set at 5% .



Asynchronous Learning in 16-cells of a Heterogeneous CNN



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