ANALOGIC CELLULAR WAVE COMPUTERS - TOPOGRAPHIC/VISUAL MICROPROCESSORS

Analog-and-logic (analogic) array computers combine analog spatial-temporal dynamics and logic. After the introduction of the CNN paradigm (CNN: Cellular Neural/nonlinear Network), CNN Technology got a boost when the analogic cellular computer architecture, the CNN Universal Machine (CNN-UM) had been invented. The most successful chips embedded in a computational infrastructure provided the framework for analogic cellular software development. Now the most advanced CNN applications rely on the available ACE16k chip designed by our Sevillian partner laboratory (http://www.imse.cnm.es/?lang=en) and the Bi-i system, developed by Analogic Computers (www.analogic-computers.com) and MTA-SZTAKI jointly. Soon, the next version of the ACE 16k chip will come out as a commercially available visual microprocessor, the Q-EYE in the Eye-RIS system at AnaFocus Ltd. Seville. References: http://www.sztaki.hu/department/Analogic

The latest development in the theoretical area included in the Cellular Wave Computer framework and its new application directions are listed below.

In view of the recent technological development, the under 100 nm size world, the Cellular Wave Computer architecture became very important, reflecting the architectures of many new devises and systems. These include the IBM-Sony-Toshiba CELL Multiprocessor chip, the Intel 80-tile processor chip, the IBM Blue Gene Supercomputer, and the CELL Broadband Engine.

Not surprisingly, the biological architectures of most of the sensory processing organs in the nervous system, in particular the mammalian retina, have very similar neuro-architectures.

The Analogic CNN Engine (ACE), the Cellular Visual Microprocessor (CVM)

The CNN paradigm related research resulted in the development of a number of analogic array processor chips. Currently, the most advanced one is the ACE16k constructed of an array of 128x128 pixel analog processor cells, all cells work parallel. The overall computational performance of the chip provides the possibility of processing 128x128 pixel-sized images up to 20,000 frame/second including I/O. Each cell in the array processor corresponds to one pixel in an image. Images larger than 128x128 can be processed tile-by-tile and then merged together again. Stored programmability with a wide operation set is the most important feature of the analog-and-logic (analogic) processor array. The operation set contains dynamic analog array operations, and local logic operations for gray-scale or binary images.

A new chip, soon commercially available by AnaFocus Ltd (www.anafocus.com), Seville, contains 25 000 (176x144) cell processors, each cell sensing R, G, B, and average intensity (altogether 100 000 focal plane sensors).

The operation and I/O accuracy of the chip is of 7-8 bits, appropriate for many applications (note that this is not equivalent to the digital accuracy, here there is no iteration in time!).

The above advantages of the ACE chips encouraged us to build the Bi-i camera (see the figure),

http://www.sztaki.hu
Bi-i Camera-Computer, the Product of The Year in Stuttgart at Vision 2003

Applications
The most recent applications of CNN technology are as follows:

- Industrial quality control
- Sensory robot control
- Security -surveillance
- Video analytics
- Unmanned Arial Vehicle (UAV) guidance
- Automotive (collision avoidance, passenger monitoring, etc)
- Medical image diagnostics
- Cellular supercomputing

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Biological relevance
Many sensory processing parts of the nervous system has the receptive field like structure, that is, in a 2D layer of neurons each one of them has connections within a finite local radius.

The mammalian retina
Very recently, after the discovery of the parallel channels in a mammalian retina in Berkeley (Nature, March 29, 2001), and based on this result, we have developed a multi-layer CNN model for reproducing some simple effects, as well as a simulation framework which is accessible from the internet. The model is illustrated below.

The multilayer CNN retina model
Some parallel channels of the mammalian retinal processing are shown schematically on the right hand side of the figure above. We use here the anatomical and physiological discoveries of the cited Nature paper to build up the layers and templates of the multilayer CNN model, as well as the measured results related to the different channels. The blobs are different cell types and the arrows are the connections between them. The first column contains the measured space-time pattern of one channel in the rabbit retina and the second column the corresponding simulated outputs. These are the excitatory current (first row), inhibitory current (middle row) and spike frequency (last row). These signals are measured/simulated as response to flashed square. Time is on the horizontal axes and the horizontal axes show the data at the center line of the square. White bars indicate the time and space occurrence of the stimulus. The parameters of the cells and templates have been tuned to get the best match with measured results. As it can be seen, the model qualitatively reproduces the patterns measured in rabbit retina.

Model tuning result for the OnAlpha and OnBeta channel of the rabbit retina.
The figures below show the model tuning in details for two channels.
Alpha cells have been found in all mammalian retina and are the homologues of parasol (M-cells) in the primate retina. Beta cells are the most frequently occurring ganglion cell type and are the homologues of midget ganglion cells (P-cells). These two channels comprise 80% of the primate ganglion cells. The black solid lines show the (normalized) measured responses and the red dashed lines are the model predictions. During the measurements, the stimulus was a flashed white square and the current measured from the ganglion cell sitting at the middle of the square. The measurement of a particular channel is repeated several times in different individual cells and/or animals. The lower curves show the average response to the flash. The upper curve shows the maximal response for a given sized square.

**Other sensory organs**
The organization of the tactile sensing has similar structures. The major challenge is the combined sensory fusion, combining visual-tactile-auditory senses.

**Cellular Supercomputers**

In addition to the Blue Gene and the CELL Broadband engine of IBM, the cellular topographic architectures are prevailing in big systems, as well as in new chips. However, we have another challenge: what if we put 1 million 8 bit microprocessors or 10 million simpler programmable processors in a chip. A new kind of computer engineering is emerging. These issues are studied in a institute-wide collaboration.

In this respect the general principle of Cellular Wave Computers and related results seem relevant. These questions open up a new way of thinking about spatial/temporal algorithms as well as about logic.

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