U.S. Office of Naval Research, International Field Office

Cellular Neural Network Review Budapest

F. Michael Pestorius and Dr. Nicholas Bottka

July, 2002

TABLE OF CONTENTS

These reports summarize global activities of S&T Associate Directors of the Office of Naval Research International Field Offices (ONRIFO).
The complete listing of newsletters and reports are available under the authors' by-line on the ONRIFO homepage: http://www.onrifo.navy.mil or by email to respective authors

Keywords

Cellular, Neural, image processing, neuro, optical processing, analogic,

1. Summary

This meeting was the third annual conference of researchers from Hungary, Spain and the US and research sponsors from ONR and ONRIFO involved in work on Cellular Neural Networks (CNN). This year's review took place 18-19 July 2002 at the Analog and Neural Computing Laboratory (ANCL), Computer and Automation Research Institute (MTA-SZTAKI) of the Hungarian Academy of Sciences in Budapest. The host was Prof. Tamás Roska of ANCL. US Navy program managers, ONRIFO, research sponsor from the Missile Defense Agency (MDA) and researchers from Hungary, Spain and the US attended. The focus of the meeting was to review progress in CNN development, assess the health of on-going projects and chart future research activities. CNN is now a reasonably mature technology and the emergence of applications is starting. There have been a large number of archival CNN publications, a recent textbook (L.O. Chua and T. Roska, Cellular Neural Networks and Visual Computing, Cambridge University Press, Cambridge, UK, 2002), and two comprehensive ONRIFO reports. The ONRIFO reports, both written by Letitia Harrison, are available at
http://www.onrifo.navy.mil/reports/2001/CNN%20HISTORY%20AND%20THEORY.doc and http://www.onrifo.navy.mil/reports/2001/Newsletter01-3.doc.
A comprehensive list of the publications up to June 2001 appears within the report at the first of the above websites. The 2001 symposium noted that CNN was on the verge of developing applications. This symposium reinforced that Idea and demonstrated some early successes.

2.Introduction

Professor Tamás Roska was the organizer and host of this meeting at the Hungarian Academy of Science. Professor Ángel Rodriguez-Vázquez of Microelectronics Research Institute of the Spanish Research Council (IMSE) Seville, Spain and Prof. Leon Chua from the University of California at Berkeley attended. These three researchers pioneered this technology. Prof. Roska has been a visiting professor at UC Berkeley since the early 90s. The origin of the CNN architecture came from collaboration between Prof. Roska and Prof. Chua. The earliest CNN course was taught at Berkeley in 1996 and there now is extensive activity in this technology. CNN has been well described in the literature (there were dozens of papers in both the archival and conference proceeding literature in the past year alone) and in the two ONRIFO reports referenced above. Hence, the explanation of CNN in this report is very brief. Basically CNN utilizes arrays of analog processors operating imbedded logic (hence the term analogic). The processors are linked to their neighbors and their output uses weighted inputs from these nearest neighbors. These processor arrays are intended to mimic the way in which human sensors and nervous systems process data into information. Using them in this manner gives them enormous TERA-op throughput for well defined problems. They appear to be especially promising for image processing tasks.

This symposium consisted of a progress report on general CNN technology by Prof. Roska, an update on chip design and fabrication by Prof. Rodriguez-Vázquez , a look into the future by Prof Chua and several specific technology reports from Hungarian researchers. The detailed material from the researchers is available from ONRIFO both on CD and in hard copy from the author of this report.

3.Technical Background

Cellular Nonlinear/Neural Network (CNN-UM) universal machine architecture is a new computational paradigm that is well suited for image processing and numerous other applications where digital technology is unable to compete in terms of speed. This stored-program array computer architecture has a solid theoretical foundation and has been implemented as a "smart sensor on a chip" using latest CMOS VLSI technology. The core of this computing technology is an array of analog processors or cells that interact with their nearest neighbors, as well as with the outside world. Their elementary instructions are complex spatio-temporal operators.

This massively parallel focal-plane array computer is now capable of processing 3 trillion equivalent digital operations per second (in analog mode) and is vastly superior to any equivalent DSP implementation by at least three orders of magnitude in either speed, power, or image area. Some of these "TeraOPS" applications include high-speed target recognition and tracking, real-time visual inspection of manufacturing processes, intelligent vision capable of recognizing context sensitive and moving scenes, as well as applications requiring real-time fusing of multiple modalities such as multi-spectral images.

A suite of design tools has been created to support the application of these chips. These tolls include high level language to describe analog-and-logic (analogic) algorithms, compiler, operating system, chip prototyping system, and a designer's tool kit. These application tools have been available for the past four years and updated versions are added each year as more sophisticated chip designs are implemented.

4.CNN Technology Overview – T. Roska

CNN was borne out of collaboration between Prof. Roska and Prof. Chua at UC Berkeley. ONR was a sponsor and supporter of this technology from the start and gave a boost to its early days through the NICOP program. TERA-ops speed and 1000 frames per second was the benchmark as recently as 1999 for a single-chip CNN visual microprocessor. Only three years later 12 TERA-ops and

10K frames per second is within reach. Optical sensing is being incorporated in individual processor cells and cell by cell adaptation to local conditions will soon be available. ANCL now has a website where researchers can submit code for testing on ANCL's CNN testbed, http://www.lab.analogic.sztaki.hu. Prof. Roska noted that there were still open theory questions regarding computational flow but that software issues were being well addressed.

5. Analogic CNN Visual Micropocessors-latest designs and forecasts – A. Rodriguez-Vazquez

The ACE4K and the ACE16K chip sets were described in Harrison's 2001 report. The ACE16K incorporates A/D and D/A converters on chip in addition to having 4 times the processor number as the ACE4K. Prof. Rodriguez-Vázquez reported on fabrication problems with the ACE16K device. Briefly, it is being refabricated by a different foundry and should be available late in 2002. This refabrication will address robustness issues in the first ACE16K design. The next design will incorporate more local processor control capability

6. Towards Molecular Implementation and other new directions of the CNN machines – L.Chua

Prof. Chua envisions CNN developing sufficiently to emulate brain and sensor functions at a molecular level. While admitting that these developments are years away he sketched out different potential architectural geometries beyond the 2-D used today. He envisions 3D "buckyball" clusters and molecular "self assembling CNN units. He also discussed locally active cells where one result triggers action in adjoining cells such that computation proceeds in a wave like manner. This speculation led to discussion of quantum computing and molecular diffusion relationships.

7. The new framework of applications The ALLADIN system - Akos Zarandy

Mr. Zarándy is a member of the Computer and Automation Research Institute of the Hungarian Academy of Science (MTA-SZTAKI). He described the first CNN technology based high performance industrial computing system, which they call ALLADIN. This system uses the ACE4K chip set and combines it with a DSP module, a frame-grabber module and a network control module for input and output control and processing. A large library function set has been developed and the resulting machine is programmable in a C environment. The ACE4K CNN processor has only parasitic visual sensing, but the next system, which is scheduled to use the ACE16K, will have direct on chip sensors. Mr. Zarándy presented execution time comparisons between the ALLADIN system and DSP solutions. The ALLADIN using library functions was routinely significantly faster than the DSP (Texas Instrument C6202@250mHz). NRL owns an ALLADIN system and is using it to develop UAV applications. The ALADDIN visual computer can be used in three modes:

(1) With a high-speed camera attached via a frame grabber, frame rate up to 5,000 fps can be reached with low resolution (64x64 to 256x256) images. In this mode the system can monitor extremely high speed events .

(2) With direct optical input on the ACE4k chip the system can deal with 64x64 size images only with a moderate frame rate. Advantage lies in its simplicity. When the ACE16k chip is integrated in the system, the unit will be capable in capturing and processing up to 10,000 128x128 size images in a second, e.g. to make 10,000 visual decisions in a rapidly changing environment. This may indeed be a unique "smart sensor" on a chip.

(3) In the third mode, the system processes video image flows from a single or multiple cameras real time. Due to the high computational power of the system, it can process whole frames, not just a small region of interest, as done by current digital image processing systems. This multi-modal image fusion has many potential DoD and industrial applications.

8. Application discussions

Several projects were presented that propose to utilize the unique biological architecture characteristics of CNN. Details are available from ONRIFO. Most of these projects had accompanying testbeds that were demonstrated to some extent. These projects include the following from MTA-SZTAKI

1. The Mammalian Retinal Model by Botund Roska (MTA-SZTAKI) and F. S. Werblin (UC Berkeley). This project focuses on modeling retinal neural physiology as a regular repeated structure of interconnected neurons. B. Roska is T. Roska’s son and is a person of great potential. He has a Hungarian MD and is a Neuro-biology PhD from UC Berkeley where he was a student of Prof. Werblin. He is starting a three year fellowship as a Harvard University fellow in biology this fall. One of ONRIFO’s roles is to identify future technology leaders. **Botund Roska is the best bet in this regard that I’ve met in my tour at ONRIFO.**
2. Implementing the Multilayer CNN retinal model on the complex CNN-UM chip by David Bálya, Csaba Rekeczky and Tomas Roska.
3. Terrain Exploration and Visual Navigation by Istvan Szatmári and Csaba Rekeczky.
4. Latest Developments in Optical Implementations by Szaboles Tökes. This work carries CNN into the optical processing domain.

The following presentations were from other laboratories:

1. Event Detection in Multidimensional Signals - The Eplilepsy Problem - Dr. Ronald Tezlaff, Frankfort university. This research is aimed at using CNN technology to identify the area of the human brain involved in epileptic activity prior to brain surgery.
2. Biomorphic Robots via CNN technology by Luigi Fortuna and Paolo Arena. This work uses CNN processes for robotic control. Dr. Joel davis of ONR presented a video of the Fortuna robot.

9.Missile Defence Agency

Dr. Paul Koskey and dr. Richard Hu represented the Missile Defense Agency (MDA) at this meeting. MDA's interest is in very high frame rate real time image processing for the detection of missile attack. They have contracted SZATKI to build a Parabolic Aperture Lens (PAL) that provides a full hemisphere of visibility up to about 60 degrees. The intention is to link this lens to the CNN processor for very high speed image processing.

10. Conclusions

CNN is a technology of promise that is on the verge of finding significant application. Its focus is very much in duplication of human sensory and neural processing and its promise is greater throughput and hence better real time performance than digital von Neumann processing. The use of the analog and analogic terms is clearly a problem for this technology. For most modern technologists, analog is a term from the past and evokes visions of gear trains and potentiometers. Hence, there is a predisposition to dismiss CNN as "old wine in new bottles". That response is wrong. CNN, with its inherently neural model and nearest neighbor processing appears to offer better performance than purely digital systems. A more mundane objection to CNN is its current spatial resolution limitation. Image processors want a 512x512 CNN array before even starting a dialogue. Such high-density chips are still far into the future. But that does not detract from the fact that the 128x128 chip and the other CMOS CNN embodiments are just around the corner. These new chips may come to dominate the image-processing field in solving certain class of problems hereto inaccessible by digital technique. ONR has shown leadership in championing this technology. Such support may well turn out to be far-sighted move by ONR.

11. List of participants at the Budapest CNN meeting

Prof. Tamas Roska, head of the Analogic Laboratory at the Computer and Automation Research Institute of the Hungarian Academy of Sciences (MTA-SZTAKI).

Prof. Leon Chua, University of California, Berkeley
Prof. Angel Rodriguez-Vazquez, Center for Microelectronics, Seville
Dr. Michael Pestorius, chief scientist ONR-IFO
Dr. Larry Cooper, program manager ONR
Dr. Joel Davis, program manager ONR
Dr. Paul Koskey, program manager MDA-OSD
Dr. Richard Hu, consultant MDA-OSD
Dr. Nicholas Bottka, consultant and visiting professor at UVA

12. Contacts

1. Ángel Rodríguez-Vázquez, Ph.D., Prof.,
Instituto de Microelectrónica de Sevilla,
Centro Nacional de Microelectrónica (IMSE-CNM)
Avda. Reina Mercedes s/n,
Edif. CICA
41012 Sevilla, Spain
Phone: +34 95 423 9923   Fax: +34 95 423 1832
e-mail: angel@imse.cnm.es

Head of a research group on Analog and Mixed-Signal VLSI at the IMSE-CNM; Design CMOS VLSI CNN 64x64 and 128x128 analogic CNN chip, leading designer of such chips; Expertise in design of embeddable interfaces for mixed signal VLSI circuits, CMOS imagers and vision chips, telecom circuits, and tools and methodologies for analog and mixed signal ICs.

National Center for Microelectronics in Spain: http://www.cnm.es/
IMSE-CNM (in Spanish): http://www.imse.cnm.csic.es/

2. Prof. Tamás Roska, Ph.D., D.Sc, Prof.,
Analogical and Neural Computing Laboratory (ANCL),
Computer and Automation Institute of the Hungarian Academy of Sciences (MTA SZTAKI)
Kende-u. 13-17, Budapest, H-1111, HUNGARY
Phone: +36 1 209 5263   Fax: +36 1 209 5264
e-mail: roska@lutra.sztaki.hu

Developed CNN operating system and compiler (Alpha); Co-inventor of the CNN Universal Machine and the analogic CNN Bionic Eye; Expertise in cellular neural networks, nonlinear circuit and systems, neural electronic circuits, and analogic spatio-temporal supercomputing.

3. Prof. Leon Chua, Ph.D., Prof.
Nonlinear Electronics Laboratory at U.C. Berkeley,
Cory Hall, University of California, Berkeley, CA 94720
Phone: (510) 642 3209 Fax: (510) 643 8869
e-mail: chua@eecs.berkeley.edu

Co-Inventor of Cellular Neural/Nonlinear Networks; Co-Inventor of CNN Universal Machine; Co-Inventor of analogic CNN bionic eye; Pioneer in nonlinear science, expert in nonlinear circuit theory and design

The Office of Naval Research International Field Office is dedicated to providing current information on global science and technology developments. Our World Wide Web home page contains information about international activities, conferences, and newsletters. The opinions and assessments in this report are solely those of the authors and do not necessarily reflect official U.S. Government, U.S. Navy or ONRIFO positions.

Return to main newsletters page