The CNN Computer - a tutorial

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Abstract. The Cellular Neural/nonlinear Network (CNN) paradigm defines a framework for continuous spatiotemporal operations via nonlinear array dynamics. The architecture of the CNN Universal Machine as well as the CNN chip set is described. The computational infrastructure of the CNN computer consists of the following parts: high level language, compiler, operating system, physical interface, as well as application development system. Some key applications will illustrate this new computing paradigm with its physical implementation parameters.

1. Introduction

The Cellular Neural /nonlinear Network (CNN) was invented in 1988 by L.O.Chua and L.Yang [1,2]. In the CNN Universal Machine (CNNUM) architecture [4], invented in 1992-93, the CNN dynamics is embedded in an array computer framework where analog array dynamics is combined by logic, locally and globally. The algorithms running on these computers are called analogic, reflecting the latter property.

Recently, the first physical implementations of the CNNUM chips has been fabricated [14-17], their computing power is about TeraOPS per cm^2. A new step in building a computer system is the Chip set architecture [36] and the construction of its physical implementation , the CNN Engine Board [39]. To prototype the CNNUM chips as the visual microprocessors, we need a CNN Chip Prototyping System [35] including a high level language with a compiler [40], an operating system , and a physical interface to the CNNUM chip. All these elements are now operational.

The world of analogic spatiotemporal CNN algorithms, hence, became practical. Indeed, the image processing implications of partial differential equations, the pattern formation properties, the propagation failure, and a few other very complex nonlinear phenomena can now be implemented and tested in a few microseconds.

In this tutorial, we summarize these results and illustrate them by practical examples.

2. Physical implementations

The CNN Universal Machine can be implemented in different ways. There ara three main directions
- analog and mixed signal CMOS [e.g. 14-17]
- emulated digital CMOS [e.g. 41] and
- optical implementations [e.g. 37].

Each implementations has its own advantage. Three typical case studies will be shown.

3. Computational infrastructure

The main elements of the computational infrastructure are
- CNN Application Development Environment and Toolkit [33]
- CNN Chip Prototyping System [34,35]

These systems will be reviewed with special emphasis on the Alpha language [40] used for describing complex spatiotemporal algorithms.

4. Algorithmic aspects and Applications

In principle, the CNN computational framework is broader than the world of partial differential equations (PDEs) in the continuous domain and than the cellular automata in the Boolean domain. To exploit these inherent potential, several projects have been carried out to solve real life problems. The application of detecting inner boundaries in Echocardiograms, fax applications, and mammogram diagnostics will be shown.

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