Learning at the Speed of Light: A New Type of Optical Neural Network

A. Steven Younger[1] and Emmett Redd[2]

[1] Jordan Valley Innovation Center, Missouri State University, Springfield, MO 65897 USA
[2] Department of Physics, Astronomy and Materials Science, Missouri State University
{SteveYounger,EmmettRedd}@MissouriState.edu

Abstract. Most, if not all, optical hardware-based neural networks are slow during the neural learning phase. This limitation has been not only a speed bottleneck, but it has contributed to the lack of wide-spread use of optical neural systems. We present a novel solution – Optical Fixed-Weight Learning Neural Networks. Standard neural networks learn new function mappings by the changing of their synaptic weights. However, the Fixed-Weight Neural Networks learn new mappings by dynamically changing recurrent neural signals. The (fixed) synaptic weights of the FWL-NN implement a learning "algorithm" which adjusts the recurrent signals toward their proper values.

Keywords: Optical Neural Networks, Optical Computing, Fixed-Weight Learning Neural Networks, Adaptive Neural Networks, Accommodative Neural Networks.

1 Introduction

Optical hardware is probably the fastest method of performing the forward-propagation phase of neural networks. An optical neural computer similar to those presented in [1, 2] should be able to perform over 10^{13} synaptic operations per second using current technology. Optical Neural squashing computations can now be performed on the sub-picoseconds time scale [3].

Most, if not all optical hardware schemes are slow during the neural learning phase. Optical learning has traditionally been done on a separate (non-optical) computer and the results stored on film, or required the use of a relatively slow (and/or expensive) spatial light modulator. This limitation has been not only a speed bottleneck, but it has contributed to the lack of wide-spread use of optical neural systems.

We present a different solution – Optical Fixed-Weight Learning Neural Networks (Optical FWL-NN). Standard neural networks learn new function mappings by the changing of their synaptic weights. However, the FWL-NNs learn new mappings by dynamically changing recurrent neural signals. The (fixed) synaptic weights of the FWL-NN implement learning "algorithm" which adjusts the recurrent signals toward their proper values. That is, instead of encoding a particular mapping, the synaptic weights of a FWL-NN encode how to learn any mapping (within a large, perhaps infinite, set of possible mappings).

S. Dolev, T. Haist, and M. Oltean (Eds.): OSC 2008, LNCS 5172, pp. 104–114, 2008.

We developed an optical hardware neural network to investigate the precision, alignment, calibration, speed, and algorithmic issues associated with Optical FWL-NNs. We report on the hardware design, generation of the synaptic weights, and initial results for some Fixed-Weight Learning tasks.

2 Optical Neural Hardware

Our optical hardware was not designed to be especially fast or to accommodate exceptionally large networks. It serves as a test apparatus for studying Optical Fixed-Weight Learning Neural Networks. Flexibility of use and (relatively) low cost were our main design criteria. With what we have learned, we are in the process of designing a fast, compact and expandable Optical Neural Network platform.

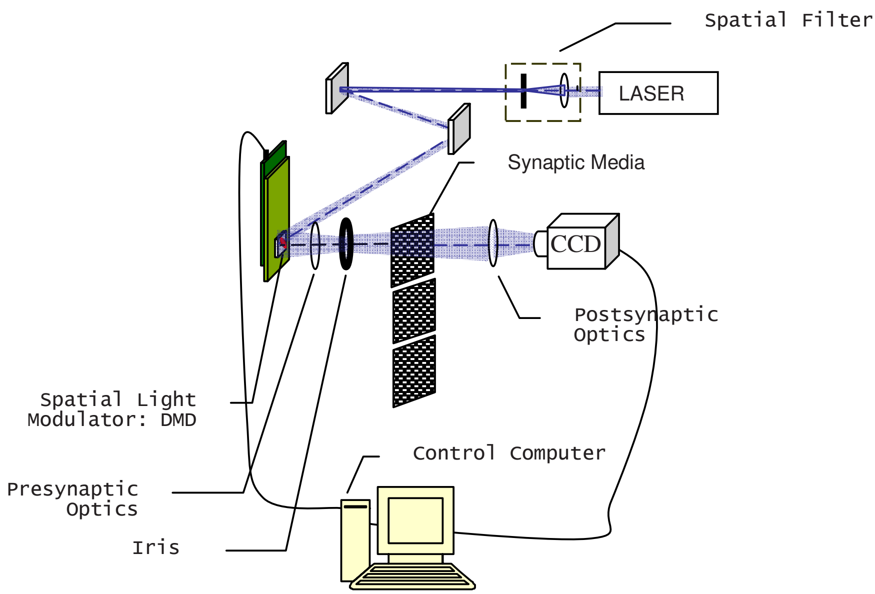

Fig. 1. Optical Neural Hardware

2.1 Hardware Overview

Figure 1 shows the optical neural hardware test apparatus. Light from a laser is expanded and directed toward a Spatial Light Modulator (SLM). The SLM creates the neural signals by modulating the intensity of a set of light beams. We used a Digital Micromirror Device (DMD) for the SLM. The DMD consists of a rectangular array of almost 1 million tiny mirrors along with drive and interfacing electronics. Under software control, each mirror can be individually set to either on (reflecting its beam toward the presynaptic optics) or off (reflecting away). The resulting signal beams pass through pre-synaptic optics and onto the synaptic medium, (35mm slide). The slide has small rectangular areas of various shades of gray that encode the synaptic