Learning of Invariances from Natural Videos

Introduction

We are exploring the learning mechanisms that result from the fact that cortical pyramidal cells have two sites of synaptic integration. It is a variant of self-supervised learning (Becker & Hinton 1992). Here we show that it is possible to learn translation invariant (complex) cells with that learning mechanism learning from natural scenes.

Two sites of synaptic integration

The apical dendrite of layer V pyramidal neurons acts, in addition to the soma, as a second site of synaptic integration (Larkum et al. 1999). The two sites interact in characterized ways:

1. to the apical dendrite by actively back-propagating dendritic action potentials.
2. to the soma via actively propagating slow regenerative calcium spikes that cause bursts.

The cellular physiology

(1) Injection of sub-threshold current into the apical dendrite leads to strongly attenuated signals at the soma.
(2) Injection of supra-threshold current into the apical dendrite leads to a calcium spike, a regenerative event and a postsynaptic burst of two spikes in this case.
(3) Injection into the soma leads to single spikes.

Following these experiments we describe each cell by two variables, somatic activity A and dendritic burst rate D.

Afferents to apical and basal dendrites

The basal dendrites receive local inhibitory projections, top down projections and long range cortico-cortical projections (Sain & Bullier 1995).

The main recipient of afferents from sensory thalamus or from areas lower in the cortical hierarchy. Thus bottom-up target inputs mainly the basal dendritic tree.

The learning

Experiments on hippocampal slices by Pike et al. (1999) support the idea that post-synaptic bursting can trigger LTP. Thus calcium spikes can trigger synaptic plasticity.

We are simulating a rate code system of neurons with a learning variable D and an Activity variable A. Cells habituate for calcium spikes, if they have not learned for a long time their weights decay upwards. Whenever the cell bursts, all synapses learn in a hebbian way.

Burst or Spikes Triggers Learning

Bottom up

Examples of stimuli

A set of pairs of stimuli is shown. Exactly these inputs are fed into our system.

Characteristics of stimuli

Orientation

Position

Input to the network

The network

3rd Layer

4 cells

2nd Layer

20 cells

Input Layer

100 cells

Our Camera Cat

A freely moving cat with a head mounted camera is used to obtain natural images. These images are analyzed with respect to their properties to analyze properties of natural scenes.

Examples of stimuli

Since the lateral geniculate nucleus acts as a filter on the inputs from the retina before they are fed into cortex we filter the inputs with an on center off surround kernel.

Preprocessing

50 subsequent images

~700 10x10 patches for each pair of images

Input to the Network

Input to the Network

Learning with two sites of synaptic integration is stable enough to allow the learning of invariances from stimuli as complex as natural scenes taken from the cat mounted camera.

Conclusion

He resulting cells are orientation specific and position invariant.

References


