A Neural Circuit to Read Out the Temporal Population Code Based on Wavelet Decomposition

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Introduction

In earlier work we have proposed that the ability of mammalian visual systems to recognize stimuli invariant to various transformations is achieved by the so called temporal population code or TPC [1] which:

- Provides high-capacity encoding
- Generalizes to realistic tasks [2]
- Direct support from physiological observations [3]

Key issue: How can TPC be decoded and what its key coding features are.

Hypothesis: wavelet coefficients can be efficiently used to decode TPC passing non-redundant, complete and dense visual information to higher order cortical structures.

To investigate the validity of this hypothesis we:

- Combine the high-capacity encoding of TPC with wavelet transform in a biological plausible circuit.
- Evaluate the network performance across different wavelet basis and over the Fourier spectrum.
- Different coefficient selection approaches are investigated: resolution level (RL) and N-biggest coefficients (NB).
- Investigate the speed of encoding of the proposed read out circuit.

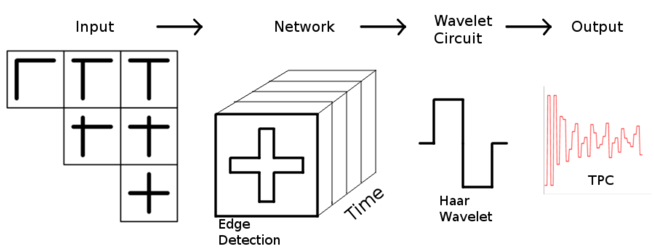

Figure 1: *The stimulus set contains six stimulus classes composed of a set of 24 different stimuli. These solid input patterns pass through an edge-detection stage and the resulting contour is presented to the network.*

Methods

TPC implementation (Fig. 1):

- The spatially integrated activity of all cells are projected, as a sum of their action potentials, onto the wavelet readout circuit.
- The TPC is represented by $\frac{S}{2^l}$ wavelet coefficients at each level l for $l = 1,2,3$, where S is the number of samples in the wavelet read-out circuit input.
- A dense representation means: coefficients that carry the greatest amount of information.
- Coefficient selection approaches: In the RL the signal is reconstructed using the coefficients of only one resolution level l; In the NB the absolute amplitude value of each coefficient among all the three resolution levels l are taken into account.
- Wavelet basis investigated: Daubechies, Symlet and Coiflet in their first five vanishing moments, in 3 resolution levels.

Results

- Evaluation of the network performance.

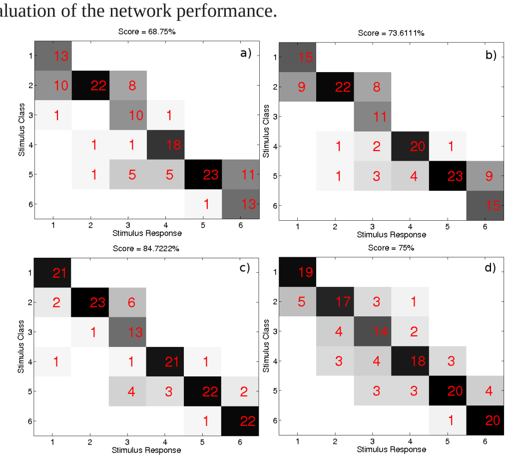

Figure 2: *Correct classification ratio for: (a) the original TPC data with correlation based classification; (b) the discrete Fourier transform, (c) discrete wavelet transform coefficients of the third detail level using the Haar basis. (d) Using the wavelet templates to classify a set of stimuli.*

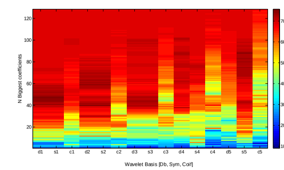

Figure 3: *After response clustering classification ratio as a function of the n biggest coefficients for all the wavelets considered in the study.*

- Speedy of encoding and TPC templates.

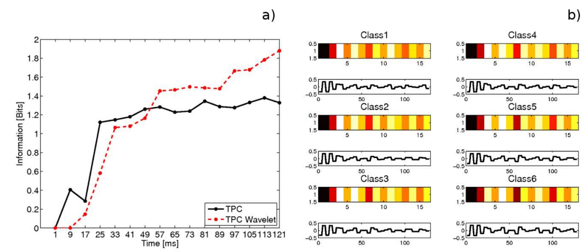

Figure 4: *a) Information encoded in the networks activity traces as a function of time. b) The templates generated of the 6 stimulus classes depicted in Fig 1.*

Conclusions

- It works.
- In comparison with the original TPC model our read-circuit improved the network performance preserving the speed of encoding.
- Haar basis seems is the best choice.
- The most relevant ammount of information is present into a single region of the time-frequency plane which is used to read-out the TPC from the templates.
- In a cortical model the wavelet coefficients can be efficiently used to decoded TPC and in a very simple and thus efficient way

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