ENCODING AND DECODING STIMULI USING A BIOLOGICALLY REALISTIC MODEL: THE NON-DETERMINISM IN SPIKE TIMINGS SEEN AS A DITHER SIGNAL

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Khaled Masmoudi [1,*], *Marc Antonini* [1], *Pierre Kornprobst* [2]

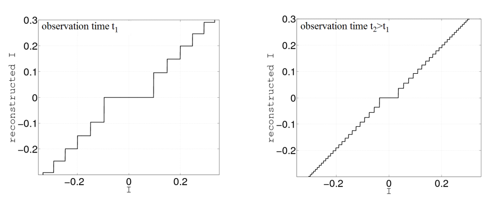
[1] Université de Nice-Sophia Antipolis–CNRS–I3S, Sophia Antipolis, France
[2] INRIA Sophia Antipolis-Méditérannée, EPI Neuromathcomp, Sophia Antipolis, France
* kmasmoud@i3s.unice.fr

The mammalians retina conveys information by means of spike trains. Though, understanding the way these spike trains represent the stimuli is still a challenging issue, especially when considering their non-determinism. Interestingly, the spike-based code of the retina is binary-like, and thus we considered its study in a signal coding fashion. To do so, we specified a coding scheme based on the mean firing rate of spikes simulated by a realistic model of the mammalians retina. We, then, inverted the generated code to reconstruct the original input. Besides, we established some links between the processing occurring in the retina and state-of-the art methods in pure image coding. Finally, we gave a biologically plausible interpretation for the non-determinism in the spike firing timings.

We based our work on the biologically realistic model of the retina introduced in [1]. This model consists in a succession of linear filters, with added nonlinearities and a novel contrast gain control model. The spike-based code generated was compared to actual neural recordings and proved to be consistent with reality. Here we focus on the three deepest retina layers of the model: bipolar, amacrine, and ganglion cells layers. We restricted this study to the time course of the filters involved, so that no spatial filtering is taken into account.

We found that the behavior of the quantizer that we specified is similar to an analog-to-digital converter with a companding stage, i.e., involving a non-linear rectification before applying a uniform quantizer with a dead zone (see below, left figure). Though, two major differences are to be mentioned. First, the bioinspired model quantizers emphasizes high magnitude signals, while classical approaches aim at refining with more accuracy low magnitudes, which are more probable (Lloyd-Max quantizer). Second, the time dimension has been introduced in the quantization mechanism. This yielded an original coding/decoding system which evolves dynamically from coarse to fine, and from uniform to non-uniform.

We interpreted the non-determinism observed in the spike firing timings as the addition of a random dither signal to the input stimuli. The dithering consists in perturbing the stimuli by a random signal ν, with ν having a specific probability distribution function [2]. Here, we identified the behavior of the retina to a non-subtractive dithered quantizer. The coding/decoding system, that we propose, offers several interesting features as (i) the time scalability as well as (ii) the reconstruction error ϵ whitening and (iii) the de-correlation of ϵ from the input stimuli. The results observed are remarkable in terms of reconstruction quality (see below, right figure).



Input signal/reconstructed signal characteristic: Behavior evolution of the bioinspired model.

Reconstruction quality with a non-dithered (left) and a dithered (right) bioinspired quantizer.

[1] A. Wohrer and P. Kornprobst, *Comp. Neurosc.*, 2009

[2] R.A. Wannamaker et al, *IEEE Trans. Signal Process.*, 2000