Capturing slow adaptation with generalized linear models

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Abstract

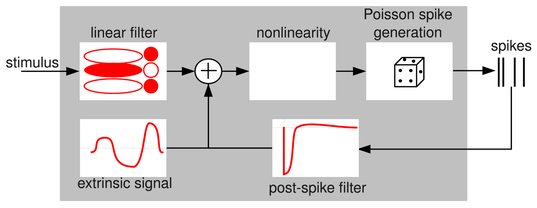
•Retinal ganglion cell firing rates adapt to luminance and contrast changes over several seconds.

• Generalized linear models (GLMs) have successfully characterized primate RGC responses to white noise.

• We show that GLMs, with spike history feedback extending back six seconds, can capture responses to a noise stimulus modulated by a log-normal contrast envelope.

• The model predicts adaptive responses to a contrast-switching stimulus that arise due to a slowly decaying inhibitory effect of previous spikes.

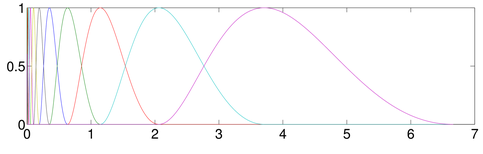
Generalized linear models



•Post-spike filters parametrized as a linear combination of raised cosine “bump” kernels extending out to six seconds.

• The extrinsic signal models variability in the spike rate at timescales slower than that of the post-spike filters.

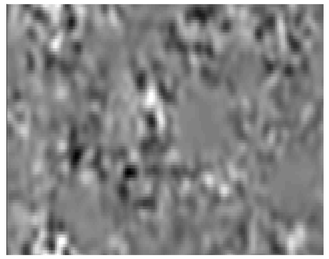
•The log-likelihood function of the model parameters (linear filter, post-spike filter, extrinsic signal) is jointly concave.



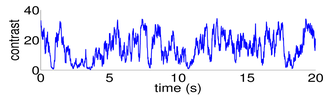
“Lava” stimulus

S(x,y,t) = B(x,y,t)C(x,y,t)
B(x,y,t)~ smoothed Gaussian noise
log(C(x,y,t)) ~ smoother Gaussian noise

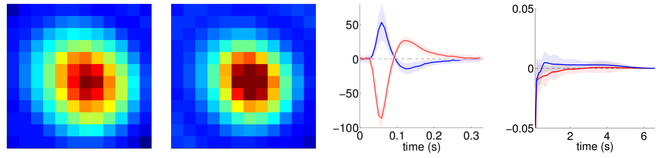
Example stimulus frame



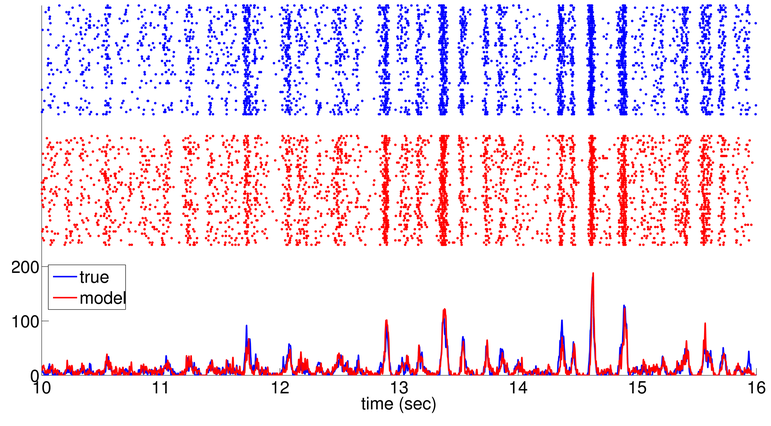
Example contrast envelope (single pixel)



Model fits

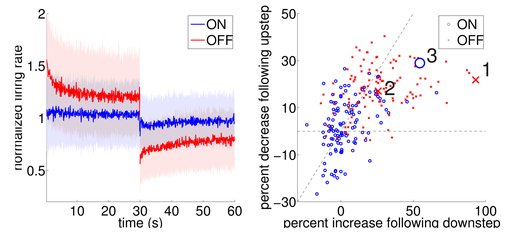


From left to right: Mean ON spatial filter; Mean OFF spatial filter; Mean temporal filter for ON (blue) and OFF (red); Mean post-spike filter tail for ON (blue) and OFF (red)

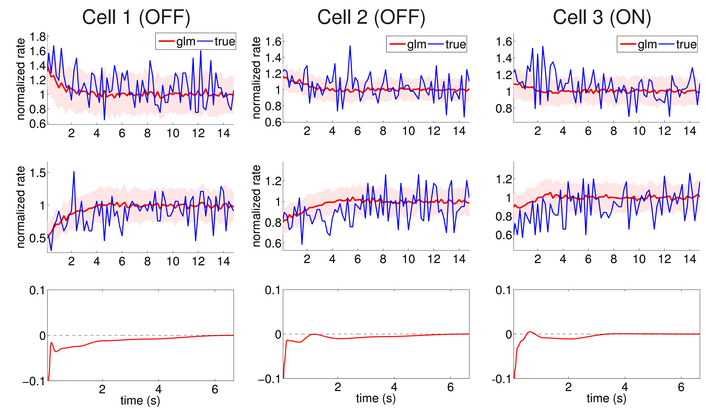


Example of a raster of responses to a repeated stimulus for the cell (blue) and fitted model (red). The PSTH of the true and model responses is also shown below.

Slow spike rate adaptation



Left: Population average response to contrast-switching stimulus for ON (blue) and OFF (red) cells. Right: Relative amounts of firing rate decrease (increase) following an increase (decrease) of contrast for ON (blue) and OFF (red) cells.



Predicted (red) and true (blue) responses to contrast-switching stimulus for the 3 cells labeled in the scatter plot . True responses averaged over 10 trials. Mean (red line) and std. dev. (red cloud) of model response calculated with 100 blocks of 10 trials each.

Conclusions

• GLMs can accurately describe responses to a novel stimulus with slowly fluctuating contrast.

• For adapting cells, the model exhibits a slow inhibitory effect of spike history, enabling it to mimic slowly adapting RGC responses to contrast-switching stimuli.

• Can a GLM also capture fast gain control (~120ms) and/or luminance adaptation?

References

[1] Baccus & Meister (2002), [2] Chander & Chichilnisky (2001, [3] Kim and Rieke (2001), [4] Fairhall (2001), [5] Pillow (2008), [6] Smirnakis (1997), [7] Truccolo (2005),