Motion-based prediction and development of the response to an 'on the way' stimulus

Mina A. Khoei, Giacomo Benvenuti, Frederic Chavane, Laurent U. Perrinet

Institut de Neurosciences de la Timone, UMR 7289, CNRS , Marseille, France

Aix-Marseille University, Marseille, France

Summary

Neuronal signature: Motion anticipation and pre-development of response to predictable trajectories

Smooth motion trajectories will generate successive and continuous stimulation of classical receptive fields (CRFs) of neighboring neuronal populations lying over retinotopic representation of the trajectory. Previous experimental studies report different temporal dynamic for neuronal codes of flashing and moving stimuli based on the history of motion *[Jancke et al 2004]*. In the experimental part of this study, we have recorded from neuronal populations of V1 in macaque monkeys, while a smoothly moving stimulus is approaching to the CRF of recorded population *[Benvenuti et al, SFN 2011]*. Bar is moving to a fixed direction but with different trajectory lengths before reaching the receptive fields of the recorded neurons. Results show a dynamic build up of an anticipatory response before arrival of stimulus to CRF.

Hypothesis: Temporal coherency of motion and internal representation of predictable trajectories

Prior information on regularities of the world is essential for optimal performance of sensory processing. In the particular case of detection of visual motion, the prior knowledge on the temporal coherency of motion facilitates estimation of predictable trajectories.

Model: motion based prediction

Based on such prior information, we have proposed a generic bayesian modeling framework to implement anisotropic diffusion of estimated motion information. This framework may serve as an internal predictive representation of motion trajectories and is suitable for explanation of neural signatures of motion processing in the visual system.

In the modeling part we aim to asses the role of prediction in the dynamical development of such a neural activity at, or before, the arrival of the sensory stimulus. To explore if such diffusive predictive mechanisms could explain neurophysiological recordings we simulated similar experiments in our model. We have used two different configuration of the model: **MBP (Motion based prediction)**, in which model holds internal representation of motion trajectory by predicting the position and velocity of stimulus and **PX (prediction of X)** in which model holds internal representation of motion trajectory by predicting only its position.

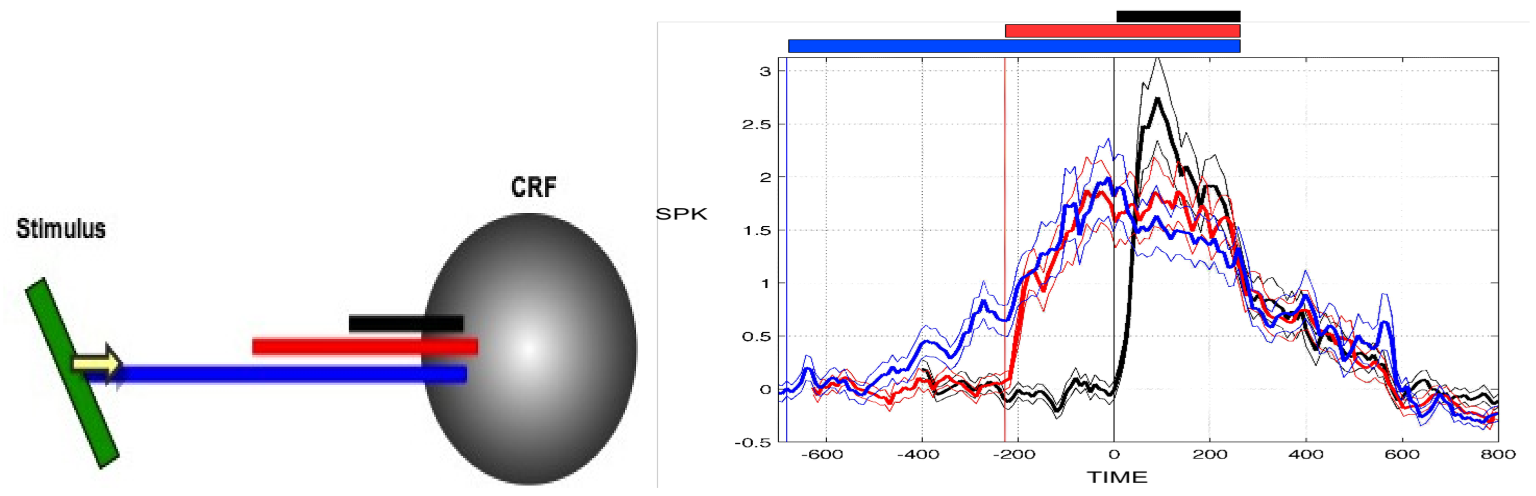

FIGURE 1: **(Left)** Experiment: a smoothly moving stimulus is approaching to the CRF of V1 population. The trajectory of the stimulus starts from different distances to CRF **(Right)** Averaged extracellular response recorded from a V1 population of macaque monkey to a moving bar with three different trajectory lengths

Model: Motion based prediction

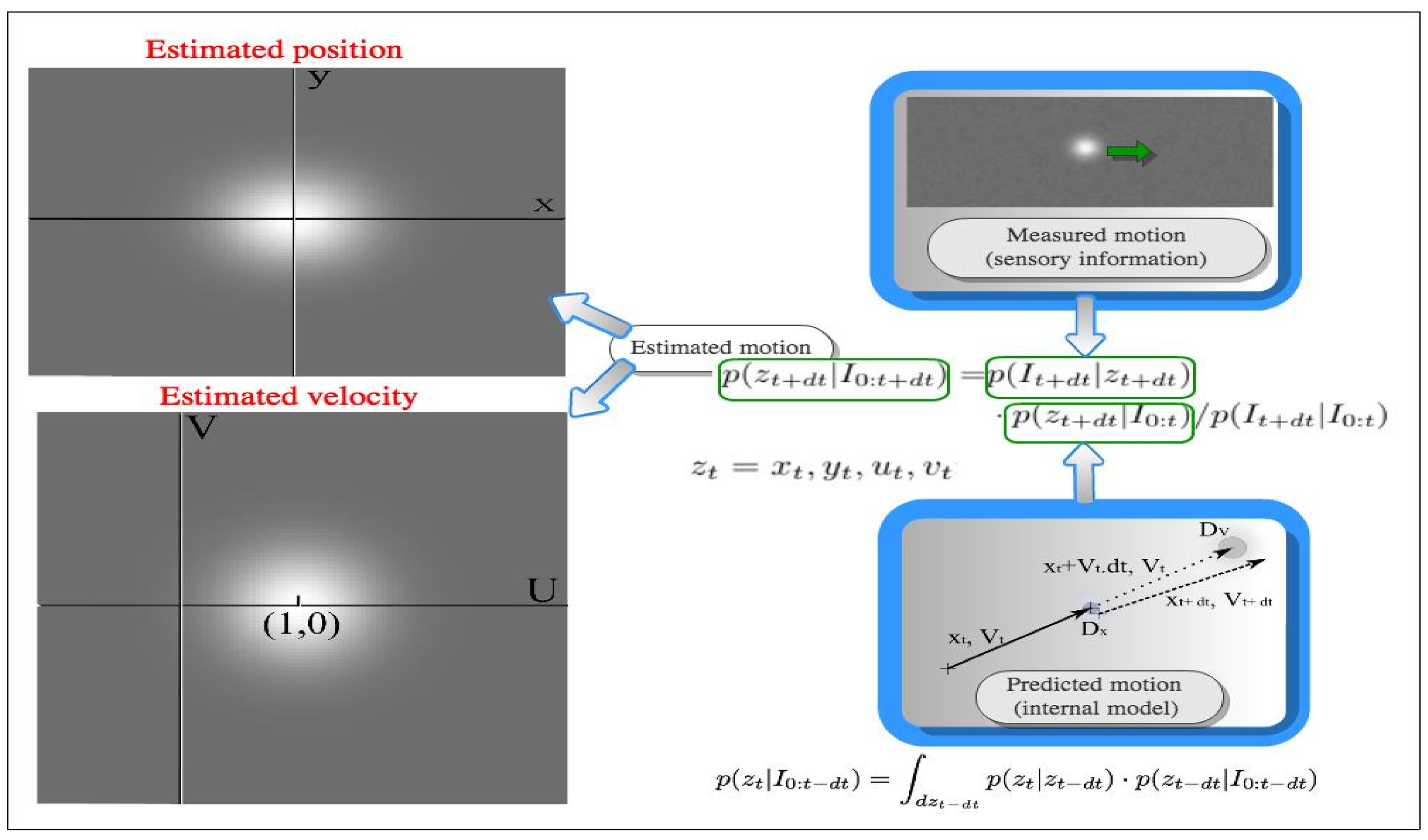

FIGURE 2: In MBP model motion is represented by probabilities associated to its position and velocity (vector Z_t). The model applies Markov chain on the states of motion while successive states are predicted by a smoothness constraint of the trajectory *[Burgi et al, 2000]* . Estimated motion is achieved after weighting predictions by current measurements. The implementation is done by CONDENSATION algorithm *[Isard et al 1998]*

Acknowledgments

This work as supported by FACETS ITN project (EU funding, grant number 237955), a 'Marie-Curie Initial Training Network'.

Results

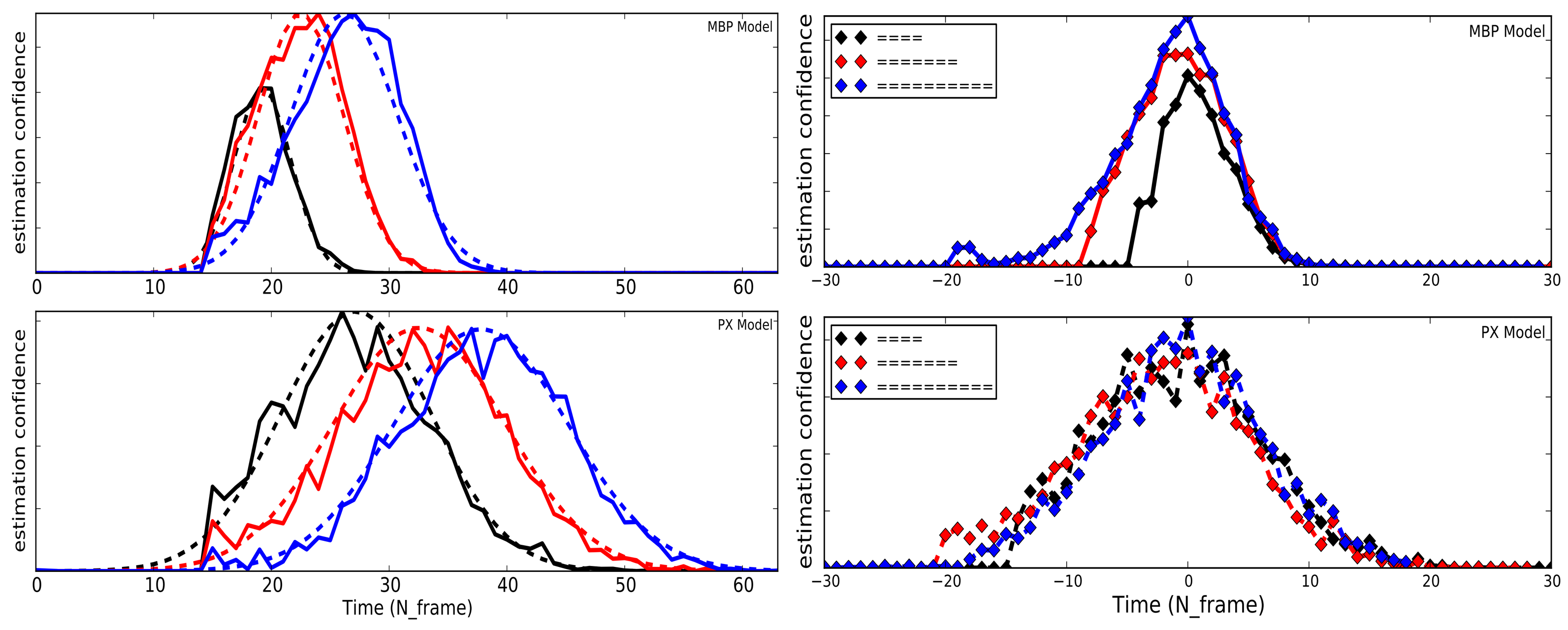

FIGURE 3: Anticipatory response in model: anticipated position of stimulus at three target points of trajectory is illustrated. Similar to the electrophysiological experiment a smoothly moving stimulus is approaching to the target points and the position of stimulus starts to build up before arrival of stimulus . Responses are averaged over 10 trials. **(Left)** In MBP model response builds up systematically before arrival of stimulus while response of PX model is delayed. **(Right)** MBP and PX models of anticipatory response centered by stimulus arrival time

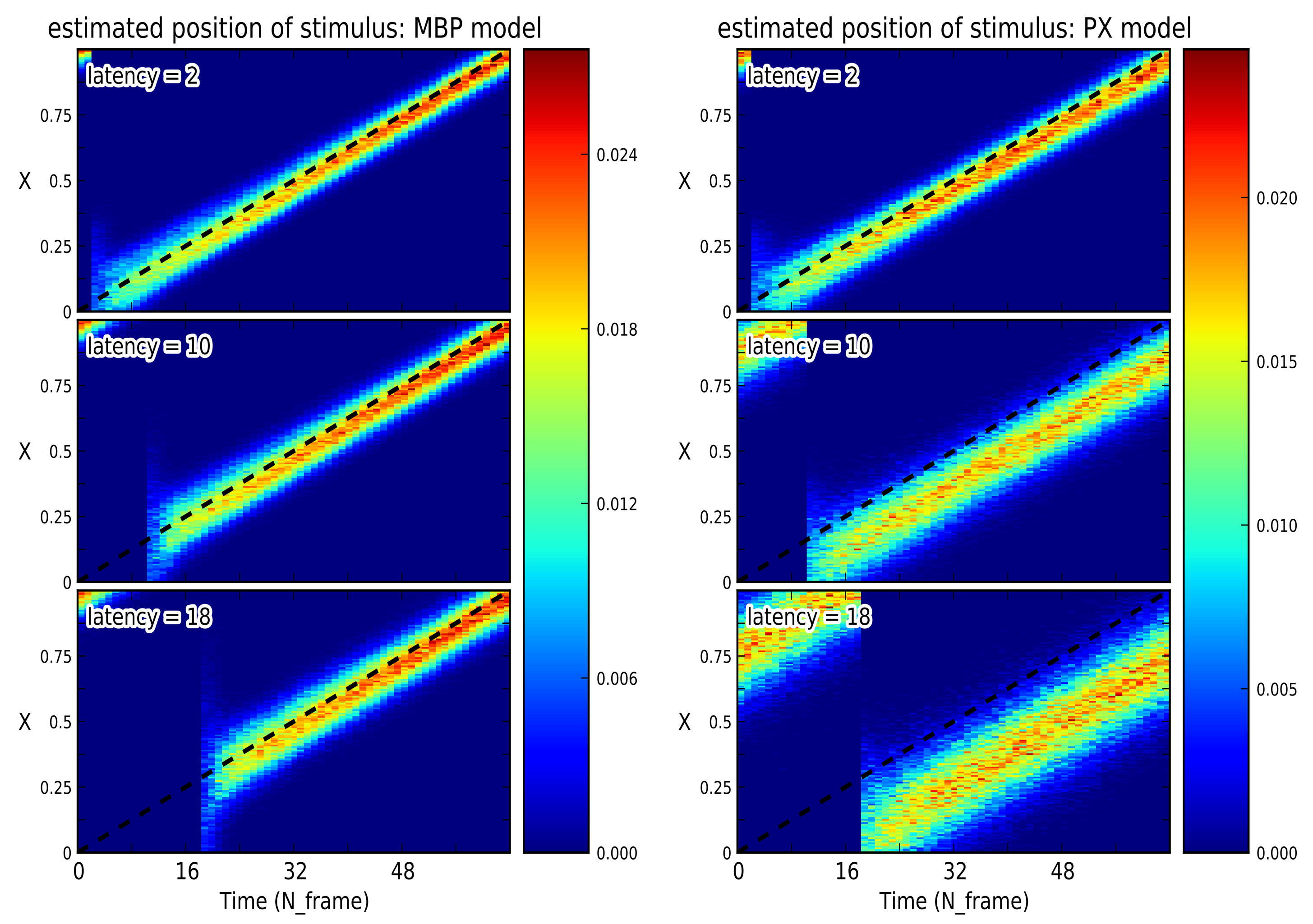

FIGURE 4: Anticipation mechanism: anticipated position of a the stimulus (a small square moving horizontally with constant velocity). Stimulus is moving from 0 to 1 (shown by dashed lines) and position estimations are illustrated as histograms composed of 400 positional bins. Color from blue to red represent the probability of each bin. **(Left)** In the MBP model, anticipatory response is developed systematically **(Right)** In PX model, increasing the length of trajectory delays and degrades the estimations

Conclusion

Motion based prediction explains anticipatory response of V1 neurons by hypothesis on the predictive internal representation of motion. As a control model we have used PX configuration in which model does not predict the velocity of stimulus. The comparison between two model reveals that having no prediction for velocity of stimulus leads to a delayed and less localized response.

References

Burgi, P.-Y., Yuille, A., & Grzywacz, N. (2000) Probabilistic motion estimation based on temporal coherence. *Neur. Computation* 12, 1839–67.

Benvenuti et al, (2011), Building a directional anticipatory response along the motion trajectory in monkey area V1, Abstracts of Society For Neuroscience

Isard, M. & Blake, A. (1998) Condensation – conditional density propagation for visual tracking. *International J. of Computer Vision* 29, 5–28.

Jancke et al, (2004) Shorter latencies for motion trajectories than for flashes in population responses of cat primary visual cortex. *The journal of physiology* 556, 971–82.