Introduction to statistical models of neural spike train data

Lectures at Institute for Research in Fundamental Sciences
Tehran, Iran.

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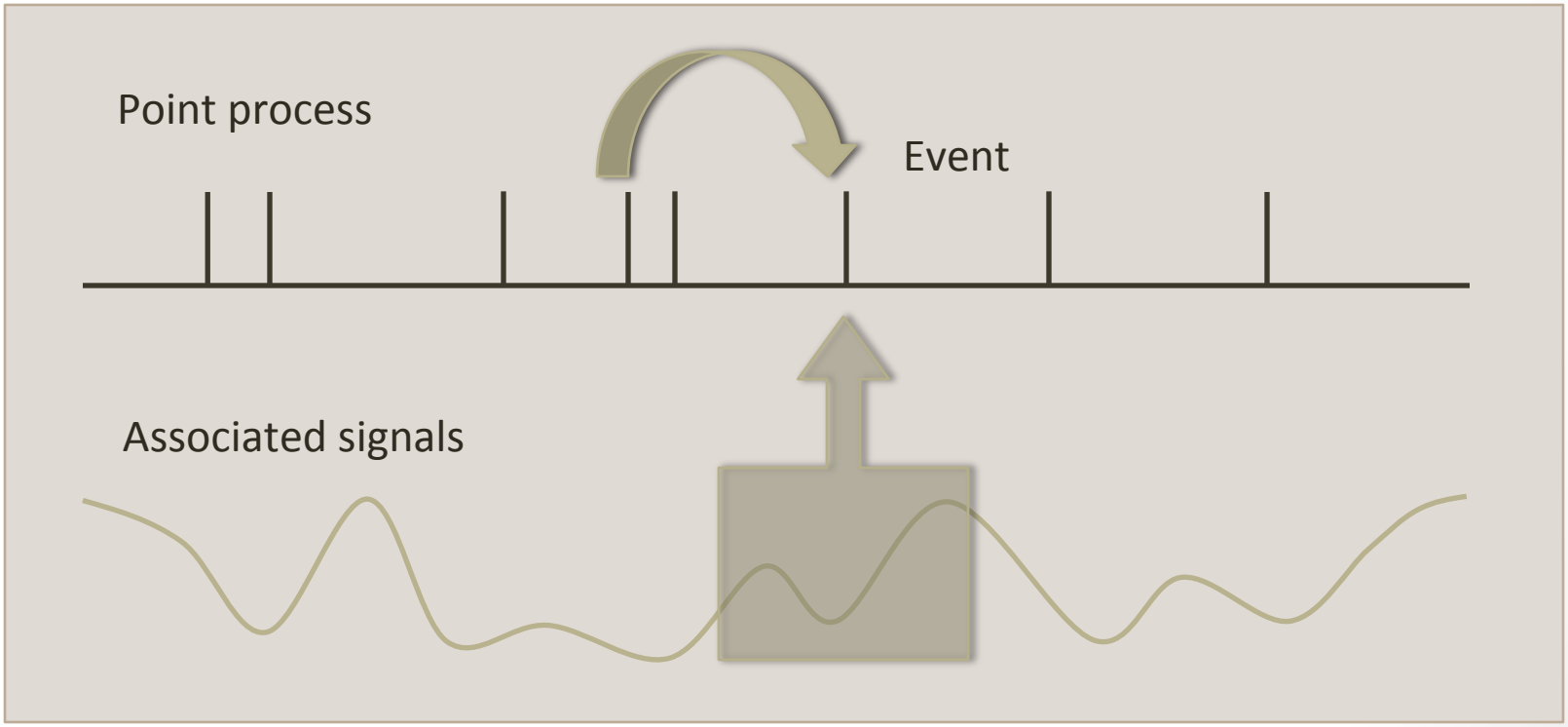
Course overview

1. Introduction and a **Poisson** point process
2. **Renewal** and **non-Poisson** processes
3. **Point process-GLM**: Stimulus and a point process (Encoding)
4. Inference for a Poisson process: **Spike-rate estimation**
5. **State-space** model and a **point process filter** (Decoding)
6. Reviews of applications

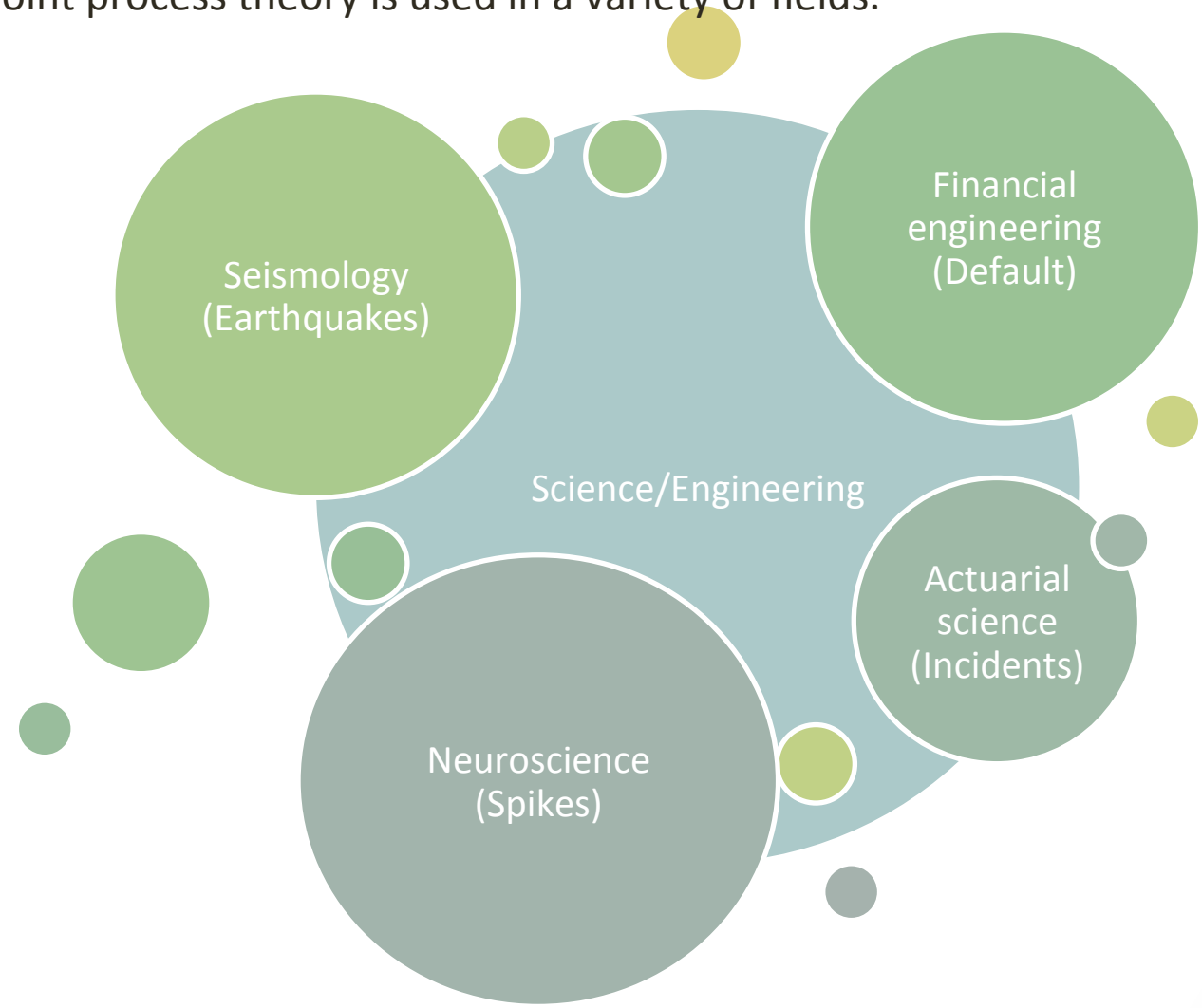
What is point process theory?

The point process theory deals with stochastic events.
It aims to formulate dependency of the events, and relations to associated signals in order to accurately predict an occurrence of the event in future.



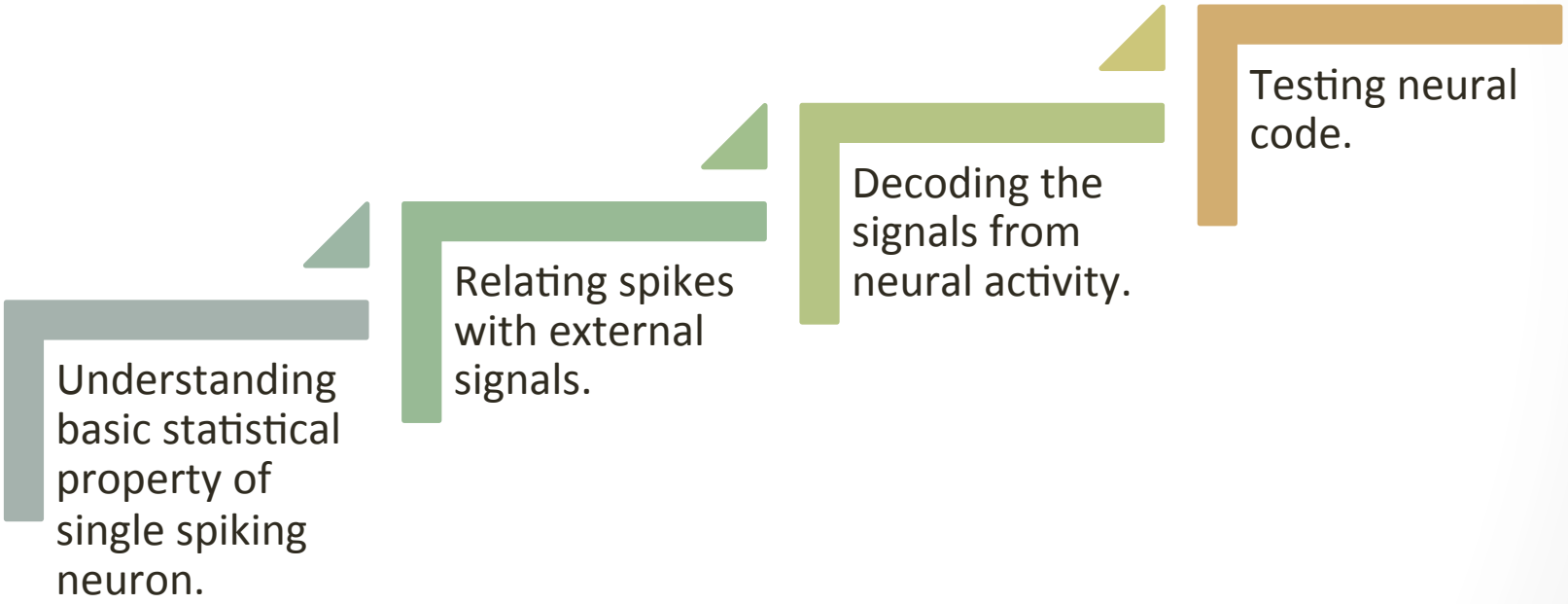
What is point process theory?

The point process theory is used in a variety of fields.



Why in the Neuroscience

Neurons are communicated by events!



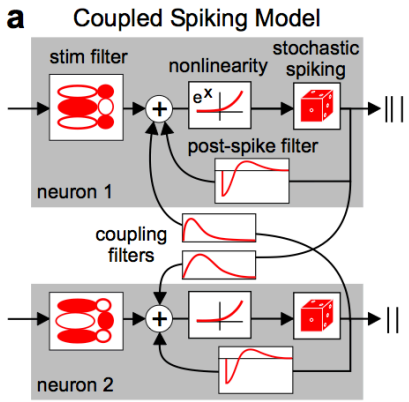
Why in the Neuroscience

Understanding basic statistical property of single spiking neuron.

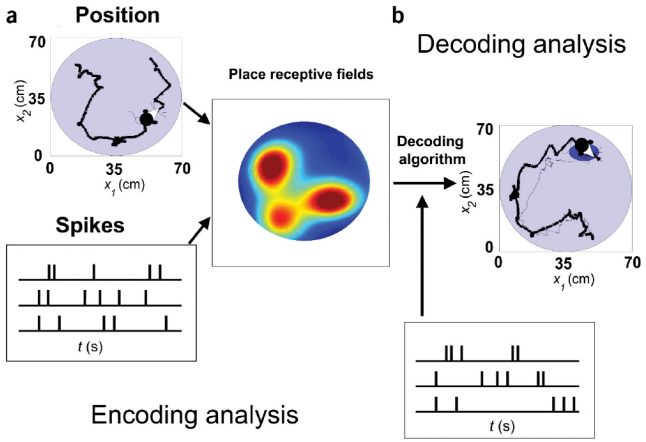
Relating spikes with external signals.

Decoding the signals from neural activity.

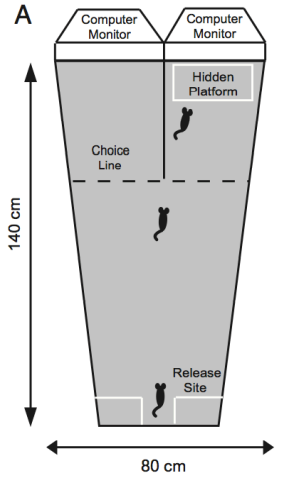
Testing neural code.



Pillow et al (2008). Nature, 454(7207), 995–999.



Brown et al. Journal of Neuroscience 1998; 18: 7411-7425.



Jacobs et al. (2009). PNAS, 106(14), 5936–41.

Selected publications

Introduction to point process theory for Neuroscience

Section 2 of Johnson, D. H. (1996). Point process models of single- neuron discharges. Journal of Computational Neuroscience, 3(4):275–299.

Kass, R. E., Ventura, V., & Brown, E. N. (2005). Statistical issues in the analysis of neuronal data. *Journal of neurophysiology*, *94*(1), 8–25.

Brown, E. N., Barbieri, R., Ventura, V., Kass, R. E., & Frank, L. M. (2001). The time-rescaling theorem and its application to neural spike train data analysis. Neural Comput, 14(2), 325–346.

Spike-rate estimation

Shimazaki, H., & Shinomoto, S. (2007). A method for selecting the bin size of a time histogram. *Neural Computation*, *19*(6), 1503–1527.

Point process-GLM

Truccolo W, Eden U, Fellow M, Donoghue JD, Brown EN. A point process framework for relating neural spiking activity to spiking history, neural ensemble and covariate effects. Journal of Neurophysiology, 2005, 93: 1074-1089.

Pillow, J. W., Shlens, J., Paninski, L., Sher, A., Litke, A. M., Chichilnisky, E. J., & Simoncelli, E. P. (2008). Spatio-temporal correlations and visual signalling in a complete neuronal population. Nature, 454(7207), 995–999.

State-space model

Brown EN, Frank LM, Tang D, Quirk MC, Wilson MA. A statistical paradigm for neural spike train decoding applied to position prediction from ensemble firing patterns of rat hippocampal place cells, Journal of Neuroscience 1998; 18: 7411-7425.

Neural coding

Jacobs, A. L., Fridman, G., Douglas, R. M., Alam, N. M., Latham, P. E., Prusky, G. T., & Nirenberg, S. (2009). Ruling out and ruling in neural codes. PNAS, 106(14), 5936–41.

Further readings

Brown, E. N., Kass, R. E., & Mitra, P. P. (2004). Multiple neural spike train data analysis: state-of-the-art and future challenges. *Nature Neuroscience*, *7*(5), 456–461.

Daley, D. and Vere-Jones, D. (1988). An Introduction to the Theory of Point Processes. Springer-Verlag, New York, USA.

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Let’s start!