

MASTER'S THESIS

The non-linear firing pattern of stochastic neuronal models

Lam, Kim Fung

Date of Award:
2000

[Link to publication](#)

General rights

Copyright and intellectual property rights for the publications made accessible in HKBU Scholars are retained by the authors and/or other copyright owners. In addition to the restrictions prescribed by the Copyright Ordinance of Hong Kong, all users and readers must also observe the following terms of use:

- Users may download and print one copy of any publication from HKBU Scholars for the purpose of private study or research
- Users cannot further distribute the material or use it for any profit-making activity or commercial gain
- To share publications in HKBU Scholars with others, users are welcome to freely distribute the permanent URL assigned to the publication

**The Non-Linear Firing Pattern of
Stochastic Neuronal Models**

LAM Kim Fung

A thesis submitted in partial fulfillment of the requirements
for the degree of
Master of Philosophy

November 2000

Hong Kong Baptist University

Abstract

During the last two years 1998-2000, the inhibition boosted firing (IBF) phenomenon have been reported in the neuronal model like the FitzHugh-Nagumo model and the Hodgkin-Huxley model. That is, the increase of inhibitory input would increase the firing rate of a neuron. Such phenomenon is impossible in deterministic dynamical systems. It can also happen in the stochastic neuronal model like integrate-and-fire model and the IF-FHN model. We extend the IF-FHN model in two respects: (a) with the diffusion coefficient (infinitesimal variance) is in a space-dependent form. (b) with the sinusoidal signals input to the neuron. For model (a), the closed integral form of mean firing time is obtained. For model (b), the analysis is mainly by simulation. In either model we have the existence of the critical input frequency so that the efferent firing rate is equal when the neuron receives purely excitatory inputs or exactly balanced inhibitory and excitatory inputs. Several properties are discussed. Our results suggest that the increasing inhibitory inputs boosting neuron firing is a universal phenomenon. This might give a new insight to the neuroscience.

Table of Contents

Declaration	i
Abstract	ii
Acknowledgements	iii
Table of Contents	iv
List of Figures	vi
1 Introduction	1
2 Stochastic Neuronal Activity	11
2.1 The Poisson Process for Neuron	11
2.2 Poisson Excitatory and Inhibitory Inputs	13
2.3 Wiener Process for nerve membrane potential	13
2.4 The Synaptic Inputs	16
3 Basic Neuronal Models	17
3.1 The Basic Models	17

3.2	Comparison between Deterministic and Stochastic Models . . .	20
3.3	Theoretical Results	23
3.4	Numerical integral of $E[T(r)]$	25
4	The IF-FHN Model with potential-dependent term in the synaptic inputs	28
4.1	The IF Model with potential-dependent term in the synaptic inputs	28
4.2	The IF-FHN Model with potential dependent term in the synaptic inputs	30
4.3	The Simulation Results of the IF-FHN Model with potential-dependent term in the synaptic inputs	32
4.4	Cramér's Approximation	36
5	The IF-FHN Model with Sinusoidal Signal Input	41
5.1	The IF-FHN Model with Sinusoidal Signal Input	41
5.2	The Simulation Results of the IF-FHN model with Sinusoidal Signal Input	43
6	Conclusion	52
A	The Necessity of the Growth and the Lipschitz Condition	55
	Bibliography	57
	Curriculum Vitae	59