Dedicated to my parents

Declaration

I certify that

- The work contained in the dissertation is original and has been done by myself under the general supervision of my supervisors.
- The work has not been submitted to any other Institute for any degree or diploma.
- I have followed the guidelines provided by Tezpur University in writing the thesis.
- I have conformed to the norms and guidelines given in the Ethical Code of Conduct of the university.
- Whenever I have used materials (data, theoretical analysis, and text) from other sources, I have given due credit to them by citing them in the text of the dissertation and giving their details in the references.

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Certificate

This is to certify that the thesis entitled **"Modeling of Non-linearities in Neuronal Dendritic Structures and Their Roles in Feature Extraction"** submitted to Tezpur University in the Department of Electronics and Communication Engineering under the School of Engineering in partial fulfillment of the award of the degree of Doctor of Philosophy in Electronics and Communication Engineering is a record of research work carried out by **Satyabrat Malla Bujar Baruah** under my supervision and guidance.

All helps received by him from various sources have been duly acknowledged. No part of this thesis has been submitted else where for award of any other degree.

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Certificate

This is to certify that the thesis entitled **"Modeling of Non-linearities in Neuronal Dendritic Structures and Their Roles in Feature Extraction"** submitted by **Mr. Satyabrat Malla Bujar Baruah** to Tezpur University in the Department of Electronics and Communication Engineering under the School of Engineering in partial fulfillment of the requirements for the award of the degree of Doctor of Philosophy in Electronics and Communication Engineering has been examined by us on ..... and found to be satisfactory.

The Committee recommends for award of the degree of Doctor of Philosophy.

Signature of Principal Supervisor Signature of External Examiner

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Satyabrat Malla Bujar Baruah

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Glossary of Terms

AIC	Active ion channel
AP	Action potentials
BC	Bipolar cells
ELFENN	Electric Field Effects in Neural Networks
fMRI	Functional magnetic resonance imaging
HLNS	Hierarchical linear-nonlinear structure
HOG	Histogram of Oriented Gradients
LG	Lateral Gyrus
LTP	Long term potentiation
LTD	Long term depression
ODS	Optimal Dataset Scale
OIS	Optimal Image Scale
ODSF	Optimal Dataset Scale F score
OISF	Optimal Image Scale F score
ON-BC	ON-bipolar cells
OFF-BC	OFF-bipolar cells
OS	Orientation-selective
OS-RGC	Orientation-selective retinal ganglion cell
PVC	Primate visual cortex
PSG	Post Lateral Gyrus
RF	Receptive field
RGC	Retinal Ganglion Cell
SNN	Spiking neural network

Symbols and Notations

Δx	Differential length
c_m	Specific membrane capacitance per unit surface area
r_m	Specific membrane resistance per unit surface area
r_a	Axial resistance per unit length
Na^+	Sodium ions
K^+	Potassium ions
Cl^-	Chlorine ions
g_{Na}	Maximum specific membrane conductance due to sodium ion channels per unit surface area
g_K	Maximum specific membrane conductance due to potassium ion channels per unit surface area
g_L	Maximum specific membrane conductance due to leakage ion channels per unit surface area
E_{Na}	Equilibrium potential for Sodium ion channels
E_K	Equilibrium potential for Potassium ion channels
E_L	Equilibrium potential for leakage ion channels
G_{Na}	Instantaneous Sodium ion channel conductance
G_K	Instantaneous Potassium ion channel conductance
G_L	Instantaneous leakage ion channel conductance
α_m	Sodium ion channel opening rate for m-gate
α_n	Potassium ion channel opening rate for n-gate
α_h	Sodium ion channel opening rate for h-gate
β_m	Sodium ion channel closing rate for m-gate
β_n	Potassium ion channel closing rate for n-gate
β_h	Sodium ion channel closing rate for h-gate
$m(t)$	Probability of open m-gate at time 't'
$n(t)$	Probability of open n-gate at time 't'
$h(t)$	Probability of open h-gate at time 't'
$V(x)$	Membrane potential at location x

$V(x+\Delta x)$	Membrane potential at location $x+\Delta x$
$V(x-\Delta x)$	Membrane potential at location $x-\Delta x$
$I_a(x)$	Axial current at location x
$I_a(x+\Delta x)$	Axial current at location $x+\Delta x$
$I_a(x-\Delta x)$	Axial current at location $x-\Delta x$
I_T	Trans-membrane current
I_{ionic}	Ionic current due to active or passive channel dynamics
I_c	Current across lipid bilayer membrane capacitance
I_{Na}	Current due to Sodium ion channel dynamics
I_K	Current due to Potassium ion channel dynamics
I_L	Current due to leakage ion channel dynamics
I_{inj}	Injected current to a fiber
$\frac{dV}{dx}$	Differential change in membrane potential per unit differential length
$\frac{dI_a}{dx}$	Differential change in axial current per unit differential length
I_{AP}	Current due to active action potential
D	Diameter of a fiber
L	Length of a fiber
R_{lon}	Bulk axial resistance of a fiber with diameter 'D' and length 'L'
G_L	Bulk leakage membrane conductance of a fiber with diameter 'D' and length 'L'
C_m	Bulk membrane capacitance of a fiber with diameter 'D' and length 'L'
I_{prop}	Propagating current from point'A' to point 'B'
$\frac{dD}{dx}$	Differential change in diameter per unit differential length
R_{ix}	Axial resistance inside fiber 'x' due to endoplasm
R_e	Extracellular resistance due to exoplasm
R_{ax}	Axial resistance to propagating signal along the axis of fiber 'x'
R_{exy}	Extracellular resistance to ionic mobility from fiber 'x' to fiber 'y'
V_e	Potential outside fiber
V_{ix}	Potential inside fiber 'x'
I_e	Extracellular current due to ionic mobility
I_{ix}	Axial current in fiber 'x'
I_{Tx}	Transmembrane current for fiber 'x'

I_{inj_x}	Injected current to fiber 'x'
I_{ion_x}	Current due to ionic exchange or leakage ions for fiber 'x'
A and B	Coupling matrices
ϕ	Forced input to the system
C_{mx}	Membrane capacitance for fiber 'x'
a	Izhikevich's control parameter for spiking activity
b	Izhikevich's control parameter for spiking activity
c	Izhikevich's control parameter for spiking activity
d	Izhikevich's control parameter for spiking activity
k	Izhikevich's control parameter for spiking activity
C	Izhikevich's control parameter for spiking activity
v	Izhikevich's membrane potential for spiking activity
u	Izhikevich's recovery current
v_t	Izhikevich's threshold potential for spiking activity
v_r	Izhikevich's resting membrane potential
I	Input stimulus to Izhikevich's membrane model
$V_{threshold}$	Threshold potential for membrane potential to consider as a spike
$V_{m(i,j)}$	Temporal membrane potential of a neuron at spatial location i^{th} row and j^{th} column
$F_x(i,j)$	Firing rate of a neuron at spatial location i^{th} row and j^{th} column