



CONTENTS

STATEMENT	iii
PREFACE	iv
ABSTRACT	v
ABSTRAK	vi
CONTENTS	vii
LIST OF FIGURES	ix
LIST OF TABLES	xi
CHAPTER I Introduction	1
1.1 Motivation	1
1.2 Problem statement	2
1.3 Contribution to research	3
1.4 Research objective	4
1.5 Research benefits	4
1.6 Thesis organization	5
CHAPTER II Nonlinear estimation	6
2.1 General nonlinear state estimation problem	6
2.2 Sub-optimal nonlinear state estimation	6
2.3 Sub-optimal nonlinear state estimator for isolated limit cycle and chaotic systems	8
CHAPTER III Nonlinearity in complex models	10
3.1 Complexity in nonlinear biological model	10
3.2 Modified Van der Pol models	11
3.2.1 2 dimensional vanilla Van der Pol model	11
3.2.2 3 dimensional chaotic Van der Pol model	11
3.2.3 4 dimensional coupled Van der Pol model	13
3.2.4 3 dimensional chaotic Van der Pol–Duffing model	14
3.2.5 Hindmarsh–Rose model of bursting–spiking neuron	15
CHAPTER IV Sigma point family: the unscented Kalman filter	17
4.1 Transformation of random variable	17
4.1.1 Linear transformation of random variable	17
4.1.2 Affine transformation of random variable	20
4.1.3 Nonlinear transformation of random variable	22
4.2 Unscented transform	26



4.2.1	Idea behind unscented transform	26
4.2.2	Performance assessment of unscented transform	28
4.2.3	Choosing sigma point and its weights	33
4.2.3.1	Sigma point computation	33
4.2.3.2	Weight computation	35
4.2.3.3	Rationale behind the parameters	35
4.3	The unscented Kalman filter	36
4.3.0.1	Square root unscented Kalman filter	38
4.3.0.2	One-step example of unscented Kalman filter	41
CHAPTER V	Square root unscented Kalman filter for isolated limit cycle and chaotic system	49
5.1	2 dimensional vanilla Van der Pol model for $\mu > 1$	49
5.2	3 dimensional chaotic Van der Pol model	49
5.3	4 dimensional coupled Van der Pol model	52
5.4	3 dimensional chaotic Van der Pol–Duffing model	57
5.5	Hindmarsh–Rose model of bursting–spiking neuron	57
CHAPTER VI	Conclusion and future work	62
REFERENCES	64
APPENDIX	L-1
L.1	'Fairly' linear function	L-1
L.2	Initial mean (\mathbf{m}_0) and covariance (\mathbf{P}_0) of the vanilla Van der Pol in subsection 4.2.2	L-1
L.3	Unscented transform parameter of the vanilla Van der Pol in sub- section 4.2.2	L-2