

Table of Content

Table of Content	iii
List of Figures	viii
Glossary	xii
1 Introduction	1
1.1 Motivation	1
1.2 Problem definition	2
1.2.1 SLAM Process and Measurement Model Dynamics	2
1.3 Hypotheses	4
1.4 Objectives	5
1.4.1 General Objective	5
1.4.2 Specific Objectives	5
1.5 Thesis structure	5
2 Literature review	7
2.1 Introduction	7
2.2 Random Finite Sets	7
2.2.1 Probability Hypothesis Density filter	8
2.2.2 The cardinality-balanced multi-target multi-Bernoulli (CB-MemBer) filter	9
2.2.3 The labelled multi Bernoulli (LMB) filter	10
2.2.4 The Generalized Labeled Multi Bernoulli (GLMB) filter	11
2.3 Simultaneous Localization and Mapping	14
2.3.1 Observability of SLAM	14
2.3.2 Vector-based SLAM	14
2.3.3 Random Finite Set-based SLAM	18
2.3.4 Evaluating SLAM performance	19
2.4 Non-linear Optimization	20

2.4.1	General unconstrained optimization	20
2.4.2	Non-linear Least Squares	21
3	Detection Statistics in SLAM	24
3.1	Introduction	24
3.2	Filtering-Based SLAM Techniques & Detection Statistics	24
3.2.1	Evaluating SLAM performance	25
3.2.2	RFS SLAM and the Importance of Detection Statistics	26
3.2.3	How do Detection Statistics Affect SLAM?	29
3.3	RFS-based batch estimation	30
4	Detection Statistics in Filter-Based SLAM	32
4.1	Introduction	32
4.2	Estimating Feature Detection Statistics Based on Range Data	34
4.2.1	Estimating Probability of Detection	34
4.2.2	Estimating Probabilities of False Alarm	37
4.3	Including Descriptor Information into SLAM	38
4.3.1	Including Descriptor Information into PHD-SLAM	38
4.3.2	Including Descriptor Information into MH-FastSLAM (MH-FastSLAM) .	41
4.3.3	Adding Descriptor Information into RB-PHD-SLAM, a Proof of Concept	41
4.4	Learning from Simulated Range Data	45
4.4.1	Estimating the Detection Probability	45
4.4.2	Estimating the probability of false alarm and intensity function	46
4.4.3	Estimating the feature likelihoods	47
4.5	Simulated SLAM Results	49
4.5.1	Using a different training dataset	53
4.6	Learning from a Park Environment	54
4.6.1	Estimating the Detection Probability	55
4.6.2	Estimating the false alarm statistics	55
4.6.3	Estimating the Feature Likelihoods	55
4.7	Experimental SLAM Results	58
4.7.1	Experiments in Parque O'Higgins, Santiago	58
4.7.2	Victoria Park dataset	62
4.8	Summary	65
5	PSO-RFS-SLAM	66
5.1	Introduction	66

5.2	Applying PSO to SLAM	66
5.2.1	Particle initialization	67
5.2.2	Particle motion	67
5.2.3	Gradient-based optimization step	67
5.3	Simulated SLAM Results	71
5.3.1	Proof of concept for RFS maximum likelihood SLAM in 1D	71
5.3.2	RFS maximum likelihood in 2D	71
5.4	Summary	79
6	RFS-based Non-linear Least Squares Optimization Approach	80
6.1	Introduction	80
6.2	A Joint Vector-Bernoulli distribution	81
6.3	A Joint Vector-GLMB distribution	82
6.3.1	Normal distribution approximation	86
6.4	Calculating the component weight	89
6.5	A visual demonstration of V-GLMB-SLAM	95
6.6	V-GLMB-SLAM implementation	100
6.6.1	A landmark birth move	103
6.6.2	A landmark death move	104
6.6.3	Sampling the associations	104
6.6.4	A note on computational complexity	105
6.7	Simulated Results	106
6.8	Stereo Visual SLAM results	125
6.8.1	Measurement Model	126
6.8.2	Motion Model	128
6.8.3	Keypose logic	128
6.8.4	Euroc Dataset results	129
6.9	Summary	145
7	Conclusions and future work	146
7.1	Future avenues of research	147
7.1.1	Random sample consensus	147
7.1.2	Association matrix	147
Bibliography		148

A List of Publications	156
A.1 Journal papers	156
A.2 Conference papers	157
B Annex	158
C Annex	160