

Contents

1	Notion and Structure of Sensor Data Fusion	1
1.1	Subject Matter	1
1.1.1	Origins of Modern Development	2
1.1.2	General Technological Prerequisites	3
1.1.3	Relation to Information Systems.	4
1.2	Characterization as a Branch of Applied Science	7
1.2.1	Pioneers of Sensor Data Fusion	7
1.2.2	Organization of the Research Community	11
1.2.3	Important Publication Platforms	11
1.3	From Imperfect Data to Situation Pictures.	11
1.3.1	Discussion of Characteristic Aspects.	13
1.3.2	Remarks on the Methods Used.	13
1.3.3	A Generic Sensor Data Fusion System	14
1.3.4	On Measuring Fusion Performance.	16
1.3.5	Tracking-Derived Situation Elements	17
1.3.6	Selected Issues in Anomaly Detection.	19
1.4	Future Perspectives of Sensor Data Fusion	22
1.4.1	New Everyday Life Applications	22
1.4.2	Discussion of Large-Scale Trends.	23
	References	25

Part I Sensor Data Fusion: Methodological Framework

2	Characterizing Objects and Sensors	31
2.1	Examples of State Quantities	31
2.2	Object Evolution Models.	33
2.2.1	Van-Keuk's Evolution Model.	33
2.2.2	Interacting Multiple Models.	34
2.3	Sensor Likelihood Functions	35
2.3.1	Gaußian Likelihood Functions	36
2.3.2	Multiple Sensor Likelihood	41
2.3.3	Likelihood for Ambiguous Data	44

2.3.4	Incorporating Signal Strength.	48
2.3.5	Extended Object Likelihood.	50
References		51
3	Bayesian Knowledge Propagation	53
3.1	Bayesian Tracking Paradigm	53
3.1.1	Characteristic Aspects.	56
3.1.2	Remarks on Approximations	57
3.1.3	On Track-to-Track Fusion	59
3.1.4	A First Look at Initiation	60
3.2	Object State Prediction	60
3.2.1	Kalman Prediction	61
3.2.2	Expectation Gates.	61
3.2.3	IMM Prediction	63
3.3	Data Update: Filtering.	64
3.3.1	Kalman Filtering	64
3.3.2	IMM Filtering	65
3.3.3	MHT Filtering	66
3.4	Object State Retrodiction.	70
3.4.1	Fixed Interval Smoothing	72
3.4.2	Continuous Time Retrodiction	73
3.4.3	IMM Retrodiction.	74
3.4.4	MHT Retrodiction	76
3.4.5	Discussion of an Example	78
References		80
4	Sequential Track Extraction	83
4.1	Well-Separated Objects	83
4.1.1	Sequential Likelihood Ratio Test	84
4.1.2	Properties Relevant to Tracking	84
4.1.3	Relation to MHT Tracking	85
4.2	Object Clusters.	86
4.2.1	Generalized Likelihood Ratio.	86
4.2.2	On Cluster Cardinality	87
References		87
5	On Recursive Batch Processing	89
5.1	Accumulated Object State Densities	89
5.1.1	Closed-Form Representations.	90
5.1.2	Discussion of Generalizations	93
5.1.3	Out-of-Sequence Measurements	95
5.1.4	Discussion of an Example	96
5.2	Solving Tracking Problems by EM.	98
5.2.1	Data Augmentation Methods	99

5.2.2	Expectation and Maximization Steps	101
5.2.3	Discussion of Problems	104
	References	104
6	Aspects of Track-to-Track Fusion	107
6.1	Full-rate Communication Fusion	108
6.1.1	Frenkel Tracklets	108
6.1.2	Tracklet Fusion	109
6.2	Arbitrary Communication Rate Fusion	109
6.2.1	Gaussian Product Densities	111
6.2.2	Distributed Filtering Update	112
6.2.3	Distributed Prediction Update	113
6.2.4	Distributed Retrodiction Update	116
6.3	Discussion of a Simulated Example	119
	References	123
 Part II Sensor Data Fusion: Selected Applications		
7	Integration of Advanced Sensor Properties	127
7.1	Finite Sensor Resolution	127
7.1.1	A Radar Resolution Model	128
7.1.2	Resolution-Specific Likelihood	131
7.1.3	A Formation Tracking Example	134
7.1.4	Resolution: Summary of Results	135
7.2	GMTI Radar: Doppler Blindness	137
7.2.1	Air-to-Ground Surveillance	137
7.2.2	A Model for Doppler Blindness	138
7.2.3	Essentials of GMTI Tracking	143
7.2.4	Effect of GMTI-Modeling	144
7.3	Main-Lobe Jamming	149
7.3.1	Modeling the Jammer Notch	149
7.3.2	Tracking Filter Alternatives	151
7.3.3	Selected Simulation Results	152
7.4	Negative Sensor Information	153
7.4.1	A Ubiquitous Notion	153
7.4.2	Lessons Learned from Examples	154
	References	155
8	Integration of Advanced Object Properties	157
8.1	Model History MHT Tracking	158
8.1.1	IMM-MHT Tracking	158
8.1.2	Performance Evaluation	160
8.1.3	IMM-MHT: Conclusions	166

8.2	Extended Object Tracking	168
8.2.1	Generalized Formalism	169
8.2.2	Extended Object Prediction	171
8.2.3	Extended Object Filtering	173
8.2.4	Extended Object Kinematics	176
8.2.5	Selected Simulation Results	177
8.2.6	Summary of Results	180
8.3	Tracking and Classification	183
	References	184
9	Integration of Topographical Information	187
9.1	Road-map Assisted Tracking	188
9.1.1	Modeling of Road Segments	189
9.1.2	Road-Constrained Densities	190
9.1.3	Quantitative Discussion	193
9.2	Track-Based Road-map Extraction	199
9.2.1	Practical Relevance	199
9.2.2	Road Node Reconstruction	200
9.2.3	Discussion of an Example	201
9.2.4	Summary of Observations	205
9.3	Integration of Ray Tracers	207
9.3.1	Multipath Propagation Prediction	207
9.3.2	Particle Filter Approach	208
9.3.3	Conclusion	208
	References	210
10	Feed-Back to Acquisition: Sensor Management	211
10.1	Information Flow in Agile-Beam Radar	212
10.2	Sensor Modeling for Phased-Array Radar	214
10.2.1	Radar Cross Section Fluctuations	214
10.2.2	Mean Received Signal-to-Noise Ratio	215
10.2.3	Detection and Measurement Process	216
10.3	Bayesian Tracking Algorithms Revisited	217
10.3.1	Predictions: Basis for Allocation Decisions	217
10.3.2	Processing of Signal Strength Information	217
10.4	Adaptive Bayesian Sensor Management	219
10.4.1	Adaptive Radar Revisit Time Control	219
10.4.2	Transmitted Radar Energy Selection	220
10.4.3	Bayesian Local Search Procedures	220
10.5	Discussion of Numerical Simulation Results	223
10.5.1	Discussion of Simulation Scenarios	223
10.5.2	Remarks on IMM Modeling Design	226
10.5.3	Gain by IMM Modelling	227
10.5.4	On the Quality of RCS Estimates	230

10.5.5	RCS Model Mismatch.	230
10.5.6	Adaptive Energy Management	231
10.6	Adaptive Sensor Management: Summary of Results	233
	References	234
Appendix A.		237