

Sensor and Data Fusion

**A Tool for Information Assessment
and Decision Making**

SECOND EDITION

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Lawrence A. Klein

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**To Jonathan, Amy, Gregory,
Maya, Theo, Cassie, and Tessa**

Contents

List of Figures	xv
List of Tables	xxi
Preface	xxv
Chapter 1 Introduction	1
Chapter 2 Multiple-Sensor System Applications, Benefits, and Design Considerations	9
2.1 Data Fusion Applications to Multiple-Sensor Systems	10
2.2 Selection of Sensors	12
2.3 Benefits of Multiple-Sensor Systems	18
2.4 Influence of Wavelength on Atmospheric Attenuation	21
2.5 Fog Characterization	24
2.6 Effects of Operating Frequency on MMW Sensor Performance	24
2.7 Absorption of MMW Energy in Rain and Fog	25
2.8 Backscatter of MMW Energy from Rain	28
2.9 Effects of Operating Wavelength on IR Sensor Performance	30
2.10 Visibility Metrics	32
2.10.1 Visibility	33
2.10.2 Meteorological range	33
2.11 Attenuation of IR Energy by Rain	34
2.12 Extinction Coefficient Values (Typical)	35
2.13 Summary of Attributes of Electromagnetic Sensors	36
2.14 Atmospheric and Sensor-System Computer Simulation Models	40
2.14.1 LOWTRAN attenuation model	40
2.14.2 FASCODE and MODTRAN attenuation models	42
2.14.3 EOSAEL sensor performance model	44
2.15 Summary	48
References	49

Chapter 3	Sensor and Data Fusion Architectures and Algorithms	53
3.1	Definition of Data Fusion	53
3.2	Level 1 Processing	57
	3.2.1 Detection, classification, and identification algorithms for data fusion	58
	3.2.1.1 Physical models	59
	3.2.1.2 Feature-based inference techniques	61
	3.2.1.3 Cognitive-based models	71
	3.2.2 State estimation and tracking algorithms for data fusion	74
	3.2.2.1 Measurement- or track-search driven search ...	75
	3.2.2.2 Correlation and association of data and tracks	75
3.3	Level 2, 3, and 4 Processing	83
	3.3.1 Situation refinement	83
	3.3.2 Impact (threat) refinement	86
	3.3.2.1 Database management	87
	3.3.2.2 Interrelation of data fusion levels in an operational setting	88
	3.3.3 Fusion process refinement	90
3.4	Level 5 Fusion: Human–Computer Interface	90
3.5	Duality of Data Fusion and Resource Management	94
3.6	Data Fusion Processor Functions	97
3.7	Definition of an Architecture	97
3.8	Data Fusion Architectures	98
	3.8.1 Sensor-level fusion	99
	3.8.2 Central-level fusion	102
	3.8.3 Hybrid fusion	103
	3.8.4 Pixel-level fusion	106
	3.8.5 Feature-level fusion	108
	3.8.6 Decision-level fusion	108
3.9	Sensor Footprint Registration and Size Considerations ...	109
3.10	Summary	110
	References	113
Chapter 4	Classical Inference.....	119
4.1	Estimating the Statistics of a Population	120
4.2	Interpreting the Confidence Interval	121
4.3	Confidence Interval for a Population Mean	122
4.4	Significance Tests for Hypotheses	127
4.5	The z -test for the Population Mean	127
4.6	Tests with Fixed Significance Level	129
4.7	The t -test for a Population Mean	132
4.8	Caution in Use of Significance Tests	135

4.9	Inference as a Decision	135
4.10	Summary	140
	References	143
Chapter 5	Bayesian Inference	145
5.1	Bayes' Rule	145
5.2	Bayes' Rule in Terms of Odds Probability and Likelihood Ratio	148
5.3	Direct Application of Bayes' Rule to Cancer Screening Test Example	150
5.4	The Monty Hall Problem (Let's Make a Deal!).....	152
	5.4.1 Case-by-case analysis	152
	5.4.2 Bayes solution.....	153
5.5	Comparison of Bayesian Inference with Classical Inference	155
5.6	Application of Bayesian Inference to Fusing Information from Multiple Sources	157
5.7	Combining Multiple Sensor Information Using the Odds Probability Form of Bayes' Rule.....	158
5.8	Recursive Bayesian Updating	159
5.9	Posterior Calculation Using Multivalued Hypotheses and Recursive Updating	161
5.10	Enhancing Underground Mine Detection Using Two Sensors whose Data are Uncorrelated.....	164
5.11	Bayesian Inference Applied to Freeway Incident Detection.....	169
	5.11.1 Problem development	169
	5.11.2 Numerical example.....	173
5.12	Fusion of Images and Video Sequence Data with Particle Filters	174
	5.12.1 Particle filter	175
	5.12.2 Application to multiple-sensor, multiple-target imagery	176
5.13	Summary	178
	References	180
Chapter 6	Dempster–Shafer Evidential Theory	183
6.1	Overview of the Process	183
6.2	Implementation of the Method.....	184
6.3	Support, Plausibility, and Uncertainty Interval.....	185
6.4	Dempster's Rule for Combination of Multiple-Sensor Data	189
	6.4.1 Dempster's rule with empty set elements	192
	6.4.2 Dempster's rule with singleton propositions	193

6.5	Comparison of Dempster–Shafer with Bayesian Decision Theory.....	194
6.5.1	Dempster–Shafer–Bayesian equivalence example.....	196
6.5.2	Dempster–Shafer–Bayesian computation time comparisons	197
6.6	Developing Probability Mass Functions.....	197
6.6.1	Probability masses derived from known characteristics of sensor data.....	198
6.6.1.1	IR sensor probability mass functions.....	199
6.6.1.2	Metal detector probability mass functions.....	201
6.6.1.3	Ground-penetrating radar probability mass functions.....	202
6.6.1.4	Probability mass functions from sensor combinations.....	205
6.6.2	Probability masses derived from confusion matrices	205
6.6.2.1	Formation of travel-time hypotheses	206
6.6.2.2	Confusion matrices	206
6.6.2.3	Computing probability mass functions	208
6.6.2.4	Combining probability masses for a selected hypothesis	210
6.7	Probabilistic Models for Transformation of Dempster–Shafer Belief Functions for Decision Making	211
6.7.1	Pignistic transferable-belief model	211
6.7.2	Plausibility transformation function.....	215
6.7.3	Combat identification example	219
6.7.3.1	Belief.....	220
6.7.3.2	Plausibility	220
6.7.3.3	Plausibility probability	221
6.7.3.4	Pignistic probability	221
6.7.4	Modified Dempster–Shafer rule of combination	222
6.7.5	Plausible and paradoxical reasoning	230
6.7.5.1	Proposed solution.....	231
6.7.5.2	Resolution of the medical diagnosis dilemma.....	232
6.8	Summary.....	233
	References.....	235
Chapter 7	Artificial Neural Networks	239
7.1	Applications of Artificial Neural Networks.....	240
7.2	Adaptive Linear Combiner	240
7.3	Linear Classifiers	241
7.4	Capacity of Linear Classifiers.....	243
7.5	Nonlinear Classifiers.....	244

	7.5.1 Madaline	244
	7.5.2 Feedforward network	245
7.6	Capacity of Nonlinear Classifiers	247
7.7	Generalization	250
	7.7.1 Hamming distance firing rule	250
	7.7.2 Training set size for valid generalization	251
7.8	Supervised and Unsupervised Learning	251
7.9	Supervised Learning Rules	252
	7.9.1 μ -LMS steepest-descent algorithm	253
	7.9.2 α -LMS error-correction algorithm	254
	7.9.3 Comparison of the μ -LMS and α -LMS algorithms	255
	7.9.4 Madaline I and II error correction rules	255
	7.9.5 Perceptron rule	256
	7.9.6 Backpropagation algorithm	258
	7.9.6.1 Training process	258
	7.9.6.2 Initial conditions	259
	7.9.6.3 Normalization of input and output vectors	260
	7.9.7 Madaline III steepest descent rule	262
	7.9.8 Dead zone algorithms	262
7.10	Other Artificial Neural Networks and Data Fusion Techniques	263
7.11	Summary	265
	References	270
Chapter 8	Voting Logic Fusion	273
	8.1 Sensor Target Reports	275
	8.2 Sensor Detection Space	276
	8.2.1 Venn diagram representation of detection space	276
	8.2.2 Confidence levels	276
	8.2.3 Detection modes	278
	8.3 System Detection Probability	279
	8.3.1 Derivation of system detection and false-alarm probability for nonnested confidence levels	279
	8.3.2 Relation of confidence levels to detection and false-alarm probabilities	281
	8.3.3 Evaluation of conditional probability	282
	8.3.4 Establishing false-alarm probability	283
	8.3.5 Calculating system detection probability	284
	8.3.6 Summary of detection probability computation model	284
	8.4 Application Example without Singleton-Sensor Detection Modes	286
	8.4.1 Satisfying the false-alarm probability requirement	286

	8.4.2 Satisfying the detection probability requirement ...	287
	8.4.3 Observations.....	288
8.5	Hardware Implementation of Voting-Logic Sensor Fusion	289
8.6	Application with singleton-sensor detection modes	290
8.7	Comparison of voting logic fusion with Dempster–Shafer evidential theory.....	292
8.8	Summary.....	292
	References	294
Chapter 9	Fuzzy Logic and Fuzzy Neural Networks	295
9.1	Conditions under Which Fuzzy Logic Provides an Appropriate Solution.....	295
9.2	Fuzzy Logic Application to an Automobile Antilock-Braking System	297
9.3	Basic Elements of a Fuzzy System	297
	9.3.1 Fuzzy sets.....	297
	9.3.2 Membership functions	298
	9.3.3 Effect of membership function widths on control.....	298
	9.3.4 Production rules	299
9.4	Fuzzy Logic Processing	299
9.5	Fuzzy Centroid Calculation	301
9.6	Balancing an Inverted Pendulum with Fuzzy Logic Control.....	303
	9.6.1 Conventional mathematical solution	303
	9.6.2 Fuzzy logic solution.....	306
9.7	Fuzzy Logic Applied to Multi-target Tracking.....	309
	9.7.1 Conventional Kalman-filter approach.....	309
	9.7.2 Fuzzy Kalman-filter approach	311
9.8	Scene Classification Using Bayesian Classifiers and Fuzzy Logic	317
9.9	Fusion of Fuzzy-Valued Information from Multiple Sources.....	321
9.10	Fuzzy Neural Networks	322
9.11	Summary.....	323
	References	326
Chapter 10	Data Fusion Issues Associated with Multiple-Radar Tracking Systems	329
10.1	Measurements and Tracks	329
10.2	Radar Trackers.....	330
	10.2.1 Tracker performance parameters	331
	10.2.2 Radar tracker design issues.....	333

10.3	Sensor Registration	335
10.3.1	Sources of registration error	337
10.3.2	Effects of registration errors	338
10.3.3	Registration requirements	339
10.4	Coordinate Conversion	342
10.4.1	Stereographic coordinates	343
10.4.2	Conversion of radar measurements into system stereographic coordinates	344
10.5	General Principle of Estimation	347
10.6	Kalman Filtering	348
10.6.1	Application to radar tracking	349
10.6.2	State-transition model	350
10.6.3	Measurement model	352
10.6.3.1	Cartesian stereographic coordinates	353
10.6.3.2	Spherical stereographic coordinates	355
10.6.3.3	Object in straight-line motion	357
10.6.4	The discrete-time Kalman filter algorithm	359
10.6.5	Relation of measurement-to-track correlation decision to the Kalman gain	363
10.6.6	Initialization and subsequent recursive operation of the filter	364
10.6.7	α - β filter	369
10.6.8	Kalman gain modification methods	369
10.6.9	Noise covariance values and filter tuning	371
10.6.10	Process noise model for tracking manned aircraft	371
10.6.11	Constant velocity target kinematic model process noise	373
10.6.12	Constant acceleration target kinematic model process noise	375
10.7	Extended Kalman Filter	377
10.8	Track Initiation in Clutter	380
10.8.1	Sequential probability ratio test	381
10.8.2	Track initiation recommendations	384
10.9	Interacting Multiple Models	385
10.9.1	Applications	385
10.9.2	IMM implementation	386
10.9.3	Two-model IMM example	389
10.10	Impact of Fusion Process Location and Data Types on Multiple-Radar State-Estimation Architectures	390
10.10.1	Centralized measurement processing	391
10.10.2	Centralized track processing using single-radar tracking	393
10.10.3	Distributed measurement processing	394

10.10.4 Distributed track processing using single-radar tracking	393
10.11 Summary	397
References	400
Chapter 11 Passive Data Association Techniques for Unambiguous Location of Targets	403
11.1 Data Fusion Options	403
11.2 Received-Signal Fusion	405
11.2.1 Coherent processing technique	407
11.2.2 System design issues	409
11.3 Angle-Data Fusion	412
11.3.1 Solution space for emitter locations	412
11.3.2 Zero-one integer programming algorithm development	415
11.3.3 Relaxation algorithm development	421
11.4 Decentralized Fusion Architecture	423
11.4.1 Local optimization of direction angle- track association	424
11.4.2 Global optimization of direction angle- track association	425
11.4.2.1 Closest approach distance metric	425
11.4.2.2 Hinge-angle metric	426
11.5 Passive Computation of Range Using Tracks from a Single-Sensor Site	428
11.6 Summary	428
References	431
Chapter 12 Retrospective Comments	433
12.1 Maturity of Data Fusion	433
12.2 Fusion Algorithm Selection	434
12.3 Prerequisites for Using Level 1 Object-Refinement Algorithms	435
Appendix A Planck Radiation Law and Radiative Transfer	441
A.1 Planck Radiation Law	441
A.2 Radiative Transfer Theory	443
References	447
Appendix B Voting Fusion with Nested Confidence Levels	449
Appendix C The Fundamental Matrix of a Fixed Continuous-Time System	451
Index	455

List of Figures

Figure 2.1	Signature-generation phenomena in the electromagnetic spectrum	12
Figure 2.2	Bistatic radar geometry.	14
Figure 2.3	Active and passive sensors operating in different regions of the electromagnetic spectrum produce target signatures generated by independent phenomena.....	15
Figure 2.4	Sensor resolution versus wavelength.	16
Figure 2.5	Sensor fusion concept for ATR using multiple sensor data.	18
Figure 2.6	Multiple-sensor versus single-sensor performance with suppressed target signatures.	19
Figure 2.7	Target discrimination with MMW radar and radiometer data.....	20
Figure 2.8	Atmospheric attenuation spectrum from 0.3 μm to 3 cm.....	22
Figure 2.9	Absorption coefficient in rain and fog as a function of operating frequency and rain rate or water concentration.....	27
Figure 2.10	Rain backscatter coefficient as a function of frequency and rain rate.....	29
Figure 2.11	Rain backscatter coefficient reduction by circular polarization.	31
Figure 2.12	IR transmittance of the atmosphere.....	31
Figure 2.13	Atmospheric transmittance in rain	35
Figure 2.14	Typical 94 GHz radar backscatter from test area in absence of obscurants.	38
Figure 2.15	Visible, mid-IR, and 94-GHz sensor imagery obtained during dispersal of water fog.....	38
Figure 2.16	Visible, mid- and far-IR, and 94-GHz sensor imagery obtained during dispersal of graphite dust along road.	39
Figure 3.1	Data fusion model showing processing levels 0 through 5.	55
Figure 3.2	Data fusion processing levels 1, 2, and 3.	56
Figure 3.3	Multilevel data fusion processing.	56
Figure 3.4	Taxonomy of detection, classification, and identification algorithms.....	58
Figure 3.5	Physical model concept.....	61
Figure 3.6	Laser radar imagery showing shapes of man-made and natural objects.	61
Figure 3.7	Classical inference concept.	62
Figure 3.8	Parametric templating concept based on measured emitter signal characteristics.	67
Figure 3.9	Parametric templating using measured multispectral radiance values.	68
Figure 3.10	Cluster analysis concept.....	69

Figure 3.11	Knowledge-based expert system concept.....	73
Figure 3.12	Taxonomy of state estimation and tracking algorithms	74
Figure 3.13	Data association as aided by prediction gates.	76
Figure 3.14	Single-level and two-level data and track association architectures.....	78
Figure 3.15	Track-splitting scenario.....	80
Figure 3.16	Situation refinement in terms of information fusion and knowledge-based systems.	84
Figure 3.17	Evolution of data to information and knowledge.....	85
Figure 3.18	Military command and control system architecture showing fusion of information from multiple sources at multiple locations	89
Figure 3.19	Data fusion and resource management architectures and processes.....	96
Figure 3.20	Sensor-level fusion.....	99
Figure 3.21	Central-level fusion.....	103
Figure 3.22	Hybrid fusion.	104
Figure 3.23	Distributed fusion architecture.....	105
Figure 3.24	Pixel-level fusion in a laser radar	107
Figure 3.25	Feature-level fusion in an artificial neural network classifier.	108
Figure 4.1	Interpretation of the standard deviation of the sample mean for a normal distribution.....	120
Figure 4.2	Central area of normal distribution included in a confidence level C	122
Figure 4.3	Interpretation of confidence interval with repeated sampling.	123
Figure 4.4	90- and 99-percent confidence intervals for specimen analysis example.	125
Figure 4.5	90-, 95-, and 99-percent confidence intervals for roadway sensor spacing example.....	127
Figure 4.6	Interpretation of two-sided P -value for metal-sheet- thickness example when sample mean = 2.98 mm.	129
Figure 4.7	Upper critical value z^* used in fixed significance level test.	130
Figure 4.8	Upper and lower $\alpha/2$ areas that appear in two-sided significance test.....	131
Figure 4.9	Comparison of t distribution with four degrees of freedom with standardized normal distribution.....	133
Figure 4.10	Hypothesis rejection regions for single-sided power of a test example.....	139
Figure 4.11	Hypothesis rejection regions for double-sided power of a test example.....	140
Figure 5.1	Venn diagram illustrating intersection of events E and H.....	146
Figure 5.2	Cancer screening hypotheses and statistics.	151

Figure 5.3	Bayesian fusion process.	157
Figure 5.4	Influence diagram for two-sensor mine detection.	165
Figure 5.5	Influence diagram for freeway event detection using data from three uncorrelated information sources.	170
Figure 6.1	Dempster–Shafer data fusion process.	184
Figure 6.2	Dempster–Shafer uncertainty interval for a proposition.	187
Figure 6.3	IR camera data showing the extracted object shape (typical).	199
Figure 6.4	IR probability mass function for cross-sectional area of a mine.	201
Figure 6.5	Metal detector raw data (typical).	201
Figure 6.6	Metal detector probability mass function for metallic area.	202
Figure 6.7	Ground-penetrating radar probability mass function for burial depth.	203
Figure 6.8	Ground-penetrating radar 2D data after background removal (typical)	204
Figure 6.9	Probability mass functions corresponding to ratio of area from metal detector to the area from ground-penetrating radar	205
Figure 6.10	Motorway section over which travel-time data were collected and analyzed.	205
Figure 6.11	Separation of travel time into four hypotheses corresponding to traffic flow conditions.	206
Figure 6.12	Confusion matrix formation	207
Figure 7.1	Adaptive linear combiner.	241
Figure 7.2	Linearly and nonlinearly separable pattern pairs	242
Figure 7.3	Adaptive linear element (Adaline)	242
Figure 7.4	Probability of training pattern separation by an Adaline.	243
Figure 7.5	Madaline constructed of two Adalines with an AND threshold logic output.	244
Figure 7.6	Threshold functions used in artificial neural networks.	245
Figure 7.7	Fixed-weight Adaline implementations of AND, OR, and MAJORITY threshold logic functions.	246
Figure 7.8	A three-layer, fully connected feedforward neural network	246
Figure 7.9	Effect of number of hidden elements on feedforward neural network training time and output accuracy for a specific problem	249
Figure 7.10	Learning rules for artificial neural networks that incorporate adaptive linear elements.	253
Figure 7.11	Rosenblatt’s perceptron.	256
Figure 7.12	Adaptive threshold element of perceptron	257
Figure 8.1	Attributes of series and parallel sensor output combinations	273
Figure 8.2	Detection modes for a three-sensor system.	277
Figure 8.3	Nonnested sensor confidence levels.	277

Figure 8.4	Detection modes formed by combinations of allowed sensor outputs.....	280
Figure 8.5	Sensor-system detection probability computation model	285
Figure 8.6	Hardware implementation for three-sensor voting logic fusion with multiple-sensor detection modes.....	289
Figure 8.7	Hardware implementation for three-sensor voting logic fusion with single-sensor detection modes.....	291
Figure 9.1	Short, medium, and tall sets as depicted in conventional and fuzzy set theory.....	296
Figure 9.2	Impact of membership function width on overlap	298
Figure 9.3	Fuzzy logic computation process.....	299
Figure 9.4	Shape of consequent membership functions for correlation-minimum and correlation-product inferencing.....	300
Figure 9.5	Defuzzification methods and relative defuzzified values.....	301
Figure 9.6	Model for balancing an inverted pendulum	303
Figure 9.7	Triangle-shaped membership functions for the inverted pendulum example	307
Figure 9.8	Fuzzy logic inferencing and defuzzification process for balancing an inverted pendulum	308
Figure 9.9	Validity membership function.....	313
Figure 9.10	Size-difference and intensity-difference membership functions.	313
Figure 9.11	Similarity membership functions.....	314
Figure 9.12	Innovation vector and the differential error antecedent membership functions.....	315
Figure 9.13	Correction vector consequent membership functions.....	316
Figure 9.14	Improving performance of the fuzzy tracker by applying gains to the crisp inputs and outputs	317
Figure 9.15	Scene classification process	317
Figure 9.16	Spatial relationships of region pairs	319
Figure 9.17	Perimeter-class membership functions.....	319
Figure 9.18	Distance-class membership functions	320
Figure 9.19	Orientation-class membership functions.....	320
Figure 9.20	Final classification for tree-covered island class.....	321
Figure 9.21	Yamakawa's fuzzy neuron.....	323
Figure 9.22	Nakamura's and Tokunaga's fuzzy neuron.....	323
Figure 10.1	Surveillance system block diagram.....	331
Figure 10.2	Elements of tracker design	338
Figure 10.3	Multiple-sensor data fusion for air defense.....	336
Figure 10.4	Registration errors in reporting aircraft position.....	339
Figure 10.5	Effect of registration errors on measurement data and correlation gates	339
Figure 10.6	East-north-up and Earth-centered, Earth-fixed coordinate	

	systems	343
Figure 10.7	Stereographic coordinates	344
Figure 10.8	Kalman-filter application to optimal estimation of the system state	349
Figure 10.9	3D radar range and azimuth measurement error geometry	353
Figure 10.10	Discrete Kalman-filter recursive operation	362
Figure 10.11	Kalman-filter update process	362
Figure 10.12	SPRT decision criteria.....	383
Figure 10.13	Interacting multiple model algorithm.....	387
Figure 10.14	Two-model IMM operation sequence	389
Figure 10.15	Centralized measurement processing	392
Figure 10.16	Centralized track processing.	393
Figure 10.17	Hybrid-centralized measurement processing.	393
Figure 10.18	Distributed measurement processing.....	395
Figure 10.19	MRT Aegis cruiser distributed measurement processing architecture.....	395
Figure 10.20	Distributed track processing.....	395
Figure 11.1	Passive sensor data association and fusion techniques for estimating location of emitters.....	404
Figure 11.2	Coherent processing of passive signals	407
Figure 11.3	Cross-correlation processing of the received passive signals.....	409
Figure 11.4	Law of sines calculation of emitter location.	409
Figure 11.5	Unacceptable emitter locations.	412
Figure 11.6	Ambiguities in passive localization of three emitter sources with two receivers	413
Figure 11.7	Ambiguities in passive localization of N emitter sources with three receivers	414
Figure 11.8	Passive localization of 10 emitters using zero–one integer programming	419
Figure 11.9	All subsets of possible emitter positions before prefiltering and cost constraints are applied.....	419
Figure 11.10	Potential emitter positions that remain after prefiltering input to zero–one integer programming algorithm.....	420
Figure 11.11	Average scan-to-scan association error of auction algorithm over 15 scans	424
Figure 11.12	Varad hinge angle.....	427
Figure A.1	Radiative transfer in an Earth-looking radiometer sensor.....	443
Figure A.2	Definition of incidence angle θ	444
Figure B.1	Nested sensor confidence levels.....	449

List of Tables

Table 2.1	Common sensor functions and their implementations in precision guided weapons applications.....	11
Table 2.2	Radar spectrum letter designations	13
Table 2.3	Extinction coefficient model for snow.....	23
Table 2.4	Influence of MMW frequency on sensor design parameters	25
Table 2.5	Approximate ranges of extinction coefficients of atmospheric obscurants.....	36
Table 2.6	Electromagnetic sensor performance for object discrimination and state estimation.....	37
Table 2.7	LOWTRAN 7 input-card information	41
Table 2.8	LOWTRAN aerosol profiles.....	42
Table 2.9	PcEOSAEL modules and their functions.....	45
Table 3.1	Object discrimination categories.....	57
Table 3.2	Feature categories and representative features used in developing physical models.....	60
Table 3.3	Keno payoff amounts as a function of number of correct choices..	70
Table 3.4	Comparison of statistical, syntactic, and neural pattern recognition (PR) approaches.....	72
Table 3.5	Distance measures.....	77
Table 3.6	Suggested data and track association techniques for different levels of tracking complexity.....	82
Table 3.7	Human–computer interaction issues in an information fusion context.....	92
Table 3.8	Data fusion and resource management dual processing levels.....	95
Table 3.9	Data fusion and resource management duality concepts	96
Table 3.10	Signature-generation phenomena.....	100
Table 3.11	Sensor, target, and background attributes that contribute to object signature characterization.....	101
Table 3.12	Comparative attributes of sensor-level and central-level fusion...	104
Table 3.13	Advantages and issues associated with a distributed fusion architecture.....	106
Table 4.1	Standard normal probabilities showing z^* for various confidence levels.....	122
Table 4.2	Relation of upper p critical value and C to z^*	130
Table 4.3	Values of t^* for several confidence levels and degrees of freedom	134
Table 4.4	Comparison of z -test and t -test confidence intervals	135
Table 4.5	Type 1 and Type 2 errors in decision making.....	136

Table 4.6	Characteristics of classical inference.....	142
Table 5.1	Possible outcomes for location of “gifts” behind the three doors.....	152
Table 5.2	Comparison of classical and Bayesian inference.....	156
Table 5.3	$P(E^k H_i)$: Likelihood functions corresponding to evidence produced by k^{th} sensor with 3 output states in support of 4 hypotheses.....	162
Table 5.4	Road sensor likelihood functions for the three-hypothesis freeway incident detection problem.....	173
Table 5.5	Cellular telephone call likelihood functions for the three-hypothesis freeway incident detection problem.....	173
Table 5.6	Radio report likelihood functions for the three-hypothesis freeway incident detection problem.....	174
Table 6.1	Interpretation of uncertainty intervals for proposition a_i	187
Table 6.2	Uncertainty interval calculation for propositions $a_1, \bar{a}_1, a_1 \cup a_2, \Theta$	189
Table 6.3	Subjective and evidential vocabulary.....	189
Table 6.4	Application of Dempster’s rule.....	191
Table 6.5	Application of Dempster’s rule with an empty set.....	192
Table 6.6	Probability masses of nonempty set elements increased by K	193
Table 6.7	Application of Dempster’s rule with singleton events.....	194
Table 6.8	Redistribution of probability mass to nonempty set elements.....	194
Table 6.9	Probability masses for travel-time hypotheses from ILDs vs. true values from all toll collection data over a 24-hour period.....	209
Table 6.10	Probability masses for travel-time hypotheses from ETC vs. true values from all toll collection data over a 24-hour period.....	209
Table 6.11	Application of Dempster’s rule for combining probability masses for travel time hypothesis h_2 from ILD and ETC data.....	210
Table 6.12	Normalized probability masses for travel-time hypotheses.....	211
Table 6.13	Probability masses resulting from conditioning coin toss evidence E_1 on alibi evidence E_2	213
Table 6.14	Arguments and counter arguments for selection of Mary, Peter, or Paul as the assassin.....	216
Table 6.15	Pointwise multiplication of plausibility probability function $Pl_{P_{m_1}}$ by itself.....	217
Table 6.16	Normalized pointwise multiplied plausibility probability function $Pl_{P_{m_1}}$	217
Table 6.17	Probability summary using evidence set E_1 only.....	219
Table 6.18	Probability summary using evidence sets E_1 and E_2	219
Table 6.19	Probability mass values produced by the fusion process.....	220
Table 6.20	Application of ordinary Dempster’s rule to $B \oplus B_1$	224

Table 6.21	Normalized ordinary Dempster's rule result for $B \oplus B_1$ ($K^{-1} = 0.76$).....	225
Table 6.22	Application of modified Dempster's rule to $B \oplus B_1$	225
Table 6.23	Normalized modified Dempster's rule result for $B \oplus B_1$ ($K^{-1} = 0.412$).....	226
Table 6.24	Application of ordinary Dempster's rule to $B \oplus B_2$	226
Table 6.25	Normalized ordinary Dempster's rule result for $B \oplus B_2$ ($K^{-1} = 0.76$).....	226
Table 6.26	Application of modified Dempster's rule to $B \oplus B_2$	226
Table 6.27	Normalized modified Dempster's rule result for $B \oplus B_2$ ($K^{-1} = 0.145$).....	227
Table 6.28	Application of ordinary Dempster's rule to $B \oplus B_3$	227
Table 6.29	Application of modified Dempster's rule to $B \oplus B_3$	227
Table 6.30	Normalized modified Dempster's rule result for $B \oplus B_3$ ($K^{-1} = 0.0334$).....	227
Table 6.31	Application of ordinary Dempster's rule to $B \oplus B_4$	228
Table 6.32	Normalized ordinary Dempster's rule result for $B \oplus B_4$ ($K^{-1} = 0.52$).....	228
Table 6.33	Application of modified Dempster's rule to $B \oplus B_4$	228
Table 6.34	Normalized modified Dempster's rule result for $B \oplus B_4$ ($K^{-1} = 0.0187$).....	228
Table 6.35	Values of ODS and MDS agreement functions for combinations of evidence from B, B_i	229
Table 6.36	Orthogonal sum calculation for conflicting medical diagnosis example (step 1).....	230
Table 6.37	Normalization of nonempty set matrix element for conflicting medical diagnosis example (step 2).....	231
Table 6.38	Two information source, two hypothesis application of plausible and paradoxical theory.....	232
Table 6.39	Resolution of medical diagnosis example through plausible and paradoxical reasoning.....	233
Table 7.1	Comparison of artificial neural-network and von Neumann architectures.....	239
Table 7.2	Truth table after training by 1-taught and 0-taught sets.....	251
Table 7.3	Truth table after neuron generalization with a Hamming distance firing rule.....	251
Table 7.4	Properties of other artificial neural networks.....	266
Table 8.1	Multiple sensor detection modes that incorporate confidence levels in a three-sensor system.....	278
Table 8.2	Distribution of detections and signal-to-noise ratios among sensor confidence levels.....	286

Table 8.3	False-alarm probabilities at the confidence levels and detection modes of the three-sensor system.	287
Table 8.4	Detection probabilities for the confidence levels and detection modes of the three-sensor system.	288
Table 8.5	Detection modes that incorporate single-sensor outputs and multiple confidence levels in a three-sensor system.	290
Table 9.1	Production rules for balancing an inverted pendulum	306
Table 9.2	Outputs for the inverted pendulum example.....	309
Table 9.3	Fuzzy associative memory rules for degree_of_similarity.	314
Table 9.4	Fuzzy associative memory rules for the fuzzy state correlator.	316
Table 9.5	Spatial relationships for scene classification.	318
Table 10.1	Measures of quality for tracks.....	331
Table 10.2	Critical performance parameters affecting radar tracking.	332
Table 10.3	Potential solutions for correlation and maneuver detection.....	335
Table 10.4	Registration error sources	337
Table 10.5	Tracking performance impacts of registration errors.....	340
Table 10.6	Registration bias error budget.....	342
Table 10.7	Position and velocity components of Kalman gain vs. noise-to-maneuver ratio.	370
Table 10.8	Multisensor data fusion tracking architecture options.	392
Table 10.9	Operational characteristics of data fusion and track management options.	396
Table 10.10	Sensor and data fusion architecture implementation examples.	397
Table 11.1	Fusion techniques for associating passively acquired data to locate and track multiple targets.	406
Table 11.2	Major issues influencing the design of the coherent receiver fusion architecture.....	410
Table 11.3	Speedup of relaxation algorithm over a branch-and-bound algorithm (averaged over 20 runs).....	422
Table 12.1	Information needed to apply classical inference, Bayesian inference, Dempster–Shafer evidential theory, artificial neural networks, voting logic, fuzzy logic, and Kalman filtering data fusion algorithms to target detection, classification, identification, and state estimation.....	437
Table A.1	Effect of quadratic correction term on emitted energy calculated from Planck radiation law ($T = 300$ K)	442
Table A.2	Downwelling atmospheric temperature T_D and atmospheric attenuation A for a zenith-looking radiometer	446

Preface

Sensor and Data Fusion: A Tool for Information Assessment and Decision Making, Second Edition is the latest embodiment of a series of books I have published with SPIE beginning in 1993. The information in this edition has been substantially expanded and updated to incorporate additional sensor and data fusion methods and application examples.

The book serves as a companion text to courses taught by the author on multi-sensor, multi-target data fusion techniques for tracking and identification of objects. Material discussing the benefits of multi-sensor systems and data fusion originally developed for courses on advanced sensor design for defense applications was utilized in preparing the original edition. Those topics that deal with applications of multiple-sensor systems; target, background, and atmospheric signature-generation phenomena and modeling; and methods of combining multiple-sensor data in target identity and tracking data fusion architectures were expanded for this book. Most signature phenomena and data fusion techniques are explained with a minimum of mathematics or use relatively simple mathematical operations to convey the underlying principles. Understanding of concepts is aided by the nonmathematical explanations provided in each chapter.

Multi-sensor systems are frequently deployed to assist with civilian and defense applications such as weather forecasting, Earth resource monitoring, traffic and transportation management, battlefield assessment, and target classification and tracking. They can be especially effective in defense applications where volume constraints associated with smart-weapons design are of concern and where combining and assessing information from noncollocated or dissimilar sensors and other data sources is critical. Packaging volume restrictions associated with the construction of fire-and-forget missile systems often restrict sensor selection to those operating at infrared and millimeter-wave frequencies. In addition to having relatively short wavelengths and hence occupying small volumes, these sensors provide high resolution and complementary information as they respond to different signature-generation phenomena. The result is a large degree of immunity to inclement weather, clutter, and signature masking produced by countermeasures. Sensor and data fusion architectures enable the information from the sensors to be combined in an efficient and effective manner.

High interest continues in defense usage of data fusion to assist in the identification of missile threats and other strategic and tactical targets,

assessment of information, evaluation of potential responses to a threat, and allocation of resources. The signature-generation phenomena and fusion architectures and algorithms presented continue to be applicable to these areas and the growing number of nondefense applications.

The book chapters provide discussions of the benefits of infrared and millimeter-wave sensor operation including atmospheric effects; multiple-sensor system applications; and definitions and examples of sensor and data fusion architectures and algorithms. Data fusion algorithms discussed in detail include classical inference, which forms a foundation for the more general Bayesian inference and Dempster–Shafer evidential theory that follow; artificial neural networks; voting logic as derived from Boolean algebra expressions; fuzzy logic; and Kalman filtering. Descriptions are provided of multiple-radar tracking systems and architectures, and detection and tracking of objects using only passively acquired data. The book concludes with a summary of the information required to implement each of the data fusion methods discussed.

Although I have strived to keep the mathematics as simple as possible and to include derivations for many of the techniques, a background in electrical engineering, physics, or mathematics will assist in gaining a more complete understanding of several of the data fusion algorithms. Specifically, knowledge of statistics, probability, matrix algebra, and to a lesser extent, linear systems and radar detection theory are useful.

Several people have made valuable suggestions that were incorporated into this edition. Martin Dana, with whom I taught the multi-sensor, multi-target data fusion course, reviewed several of the newer sections and contributed heavily to Chapter 10 dealing with multiple-sensor radar tracking and architectures. His insightful suggestions have improved upon the text. Henry Heidary, in addition to his major contributions to Chapter 11, reviewed other sections of the original manuscript. Sam Blackman reviewed the original text and provided several references for new material that was subsequently incorporated. Pat Williams reviewed sections on tracking and provided data concerning tracking-algorithm execution times. Tim Lamkins, Scott McNeill, Eric Pepper, and the rest of the SPIE staff provided technical and editorial assistance that improved the quality of the text.

Lawrence A. Klein

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