Cumulative Index to the Applied Statistics Algorithms

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Chapter 1

Introduction

We present an index of all the algorithms which have been published in Applied Statistics between 1968 and 1991 inclusive. The algorithms have been classified using a modified version of the GAMS (Guide to Available Mathematical Software) Problem Classification Scheme given by Boisvert et al. [2]. This is an updated version of the scheme which appeared in Boisvert et al. [1] and has been considerably expanded especially in the statistical area. GAMS is a variable depth classification scheme. The first character, which is always a capital letter, gives the major subject area, further subdivisions are recursively denoted by alternating numbers and lower case letters. Thus, for example, D3a4 is in the main classification area of Linear Algebra (D), subarea Determinants (3), sub-subarea Real Nonsymmetric Matrices (a), sub-sub-subarea Sparse (4). The full classification list is reproduced in Chapter 4.

Although each algorithm has been classified using the full GAMS index, only the first two fields have been used to generate the cumulative index presented in Chapter 2. Each algorithm entry consists of three fields. The first field gives the algorithm number. An asterisk in this field indicates that the algorithm appears in the book of Griffiths and Hill [3]. The second field is the title of the algorithm followed by the implementation language (F for Fortran, A for Algol 60, P for Pascal and PL1 for PL/1). If the algorithm appears in Griffiths and Hill [3] then the implementation language is given as that used in the book. The final field gives all published references to the algorithm: the original publication (in bold) followed by any remarks and corrections to the algorithm which have subsequently been published. All references are of the form AS*volume*:*page*. The full GAMS classification for each algorithm is given in Chapter 3.

The form of the database entries from which the index was generated is described by Hopkins and Morse in [6] and [4]. A short description has been given in Appendix B. The database will be updated at regular intervals and the authors would be pleased to be informed of any errors or omissions.

We have also added a perl script for performing a number of transformations on the original database. This is faster and more easily modified than the original Fortran routines. It is described in more detail in Appendix A.

An earlier version of Chapter 2 of this report appeared as [5]. In addition, this report also contains the full GAMS classification of each algorithm (Chapter 3), the GAMS classification list (Chapter 4), a description of how to obtain tools to operate on the database to generate a number of more useful output forms, where to obtain sources of the algorithms, and details of the database from which the index of algorithms was generated Appendix B.

Chapter 2

Index to the Applied Statistics Algorithms

In this chapter we present a cumulative index classified using the first two fields of the GAMS classification index. All algorithms published in *Applied Statistics* between 1968 and 1991 inclusive are included along with references to any remarks and corrections which may have appeared subsequently. The GAMS index has been slightly modified as follows

- C7 *Gamma* has been changed to *Gamma and Beta distributions*
- C8 *Error functions* has been changed to *Normal distributions and Error functions*

C : Elementary and special functions *(search also class L5)*

C1 : Integer-valued functions (e.g., floor, ceiling, factorial, binomial coefficient, permutations, combinations)

88	Generation of All ${}_NC_R$ Combinations by Simulating Nested Fortran DO Loops (F)	**AS24:374**
94	Coefficients of the Zonal Polynomials (F)	**AS25:82**
179	Enumeration of All Permutations of Multi-sets with Fixed Repetition Numbers (F)	**AS31:169**
227	Efficient Generation of all Binary Patterns by Gray Code Counting (A60)	**AS36:245**

C3 : Polynomials

10	The Use of Orthogonal Polynomials (F)	**AS17:283** AS20:117 AS20:216
42	The Use of Orthogonal Polynomials with Equal x-values (F)	**AS20:209**

C7 : Gamma and beta

32	The Incomplete Gamma Integral (F)	**AS19:285** AS34:326 AS38:423
63	The Incomplete Beta Integral (F)	**AS22:409** AS26:111
64	Inverse of the Incomplete Beta Function Ratio (F)	**AS22:411** AS26:111
103	Psi (Digamma) Function (F)	**AS25:315**
109	The Incomplete Beta Integral and the Inverse of the Incomplete Beta Function Ratio (F)	**AS26:111** AS39:309
121	Trigamma Function (F)	**AS27:97** AS40:514
123	Mixtures of Beta Distributions (F)	**AS27:104**
147	A Simple Series for the Incomplete Gamma Integral (F)	**AS29:113** AS29:229 AS34:326 AS38:423
187	Derivatives of the Incomplete Gamma Integral (F)	**AS31:330**
226	Computing Noncentral Beta Probabilities (F)	**AS36:241** AS39:311
239	Chi-squared and Incomplete Gamma Integral (F)	**AS37:466**
245	A Robust and Reliable Algorithm for the Logarithm of the Gamma Function (F)	**AS38:397**

C8 : Normal distributions and error functions

2	The Normal Integral (F)	**AS17:186** AS18:299
24	From Normal Integral to Deviate (F)	**AS18:290**
66	The Normal Integral (F)	**AS22:424**
70	The Percentage Points of the Normal Distribution (F)	**AS23:96**
111	The Percentage Points of the Normal Distribution (F)	**AS26:118**
195	Multivariate Normal Probabilities with Error Bound (F)	**AS33:81** AS34:103
241	The Percentage Points of the Normal Distribution (F)	**AS37:477**

D : Linear Algebra

D1 : Elementary vector and matrix operations

11	Normalizing a Symmetric Matrix (F)	**AS17:287**

D2 : Solution of systems of linear equations (including inversion, LU and related decompositions)

6	Triangular Decomposition of a Symmetric Matrix (F)	**AS17:195** AS23:477 AS27:379 AS31:336
7	Inversion of a Positive Semi-definite Symmetric Matrix (F)	**AS17:198** AS31:336
34	Sequential Inversion of Band Matrices (F)	**AS19:290**
37	Inversion of a Symmetric Matrix (A60)	**AS20:111** AS23:100

D3 : Determinants

82	The Determinant of an Orthogonal Matrix (F)	**AS24:150**

D4 : Eigenvalues, eigenvectors

60	Latent Roots and Vectors of a Symmetric Matrix (F)	**AS22:260** AS23:101

D5 : QR decomposition, Gram-Schmidt orthogonalization

46	Gram–Schmidt Orthogonalization (F)	**AS20:335**

G : Optimization *(search also classes K, L8)*

G1 : Unconstrained

47	Function Minimization using a Simplex Procedure (F)	**AS20:338** AS23:252 AS23:250 AS25:97 AS27:380
133	Optimization of One-Dimensional Multimodal Functions (F)	**AS27:367**

G2 : Constrained

13	Minimum Spanning Tree (A60)	**AS18:103**
14	Printing the Minimum Spanning Tree (A60)	**AS18:105**
40	Updating a Minimum Spanning Tree (F)	**AS20:204**
263	Construction of Irredundant Test Sets (F)	**AS40:213**

J : Integral transforms

J1 : Trigonometric transforms including Fast Fourier transforms

83	Complex Discrete Fast Fourier Transform (F)	**AS24:153**
97	Real Discrete Fast Fourier Transform (F)	**AS25:166**
117	The Chirp Discrete Fourier Transform of General Length (F)	**AS26:351**
186	Fast Algorithm of Data Permutation in Discrete Fast Fourier Transform (F)	**AS31:327**

K : Approximation *(search also class L8)*

K1 : Least squares (L_2) approximation

164	Least Squares Subject to Linear Constraints (F)	**AS30:204** AS30:357 AS37:484
225	Minimizing Linear Inequality Constrained Mahalanobis Distances (F)	**AS36:234**
228	Finding I-Projections Subject to a Finite Set of Linear Inequality Constraints (F)	**AS36:377**

K5 : Smoothing

222	Resistant Smoothing Using the Fast Fourier Transform (F)	**AS36:104** AS37:316

L : Statistics, probability

L1 : Data summarization

12	Sums of Squares and Products Matrix (F)	**AS17:289**
16	Maximum Likelihood Estimation from Grouped and Censored Normal Data (A60)	**AS18:110** AS26:122 AS36:119
18	Evaluation of Marginal Means (A60)	**AS18:197**
41	Updating the Sample Mean and Dispersion Matrix (F)	**AS20:206**
52	Calculation of Power Sums of Deviations about the Mean (F)	**AS21:226**
78	The Mediancentre (F)	**AS23:466** AS24:390
101	Distribution-free Confidence Intervals (F)	**AS25:309**
119	Tabulating Sparse Joint Frequency Distributions (F)	**AS26:364**
131	Tabulating Frequency Distributions for Variables with Structured Code Sets (F)	**AS27:359** AS38:582
143	The Mediancentre (F)	**AS28:325**
180	A Linear Estimator of Standard Deviation in Symmetrically Trimmed Normal Samples (F)	**AS31:174**
235	Number tally (F)	**AS37:285**
240	Updating the Inverse of the Dispersion Matrix (F)	**AS37:474**

L2 : Data manipulation

267	Probabilities and Standardized Differences for Selecting Subsets Containing the Best Populations (F)	**AS40:495**

L3 : Elementary statistical graphics *(search also class Q)*

21	Scale Selection for Computer Plots (F)	**AS18:206** AS20:118 AS23:248
30	Half Normal Plotting (F)	**AS19:192** AS20:118 AS21:351
44	Scatter Diagram Plotting (F)	**AS20:327** AS23:248

45	Histogram Plotting (F)	**AS20:332** AS22:274
61	Six-line Plots (F)	**AS22:265** AS26:368
96	A Simple Algorithm for Scaling Graphs (F)	**AS25:94**
130	Moving Statistics for Enhanced Scatter Plots (F)	**AS27:354**
168	Scale Selection and Formatting (F)	**AS30:339**
169	An Improved Algorithm for Scatter Plots (F)	**AS30:345** AS31:340 AS33:370

L4 : Elementary data analysis

29	The Runs Up and Down Test (A60)	**AS19:190** AS25:193
31	Operating Characteristic and Average Sample Size for Binomial Sequential Sampling (A60)	**AS19:197**
35	Probabilities Derived from Finite Populations (A60)	**AS20:99** AS20:346 AS21:352 AS26:221
48	Uncertainty Function for a Binary Sequence (A60)	**AS21:97**
49	Autocorrelation Function for a Binary Sequence (A60)	**AS21:100**
50	Tests of Fit for a One-hit vs. Two-hit Curve (F)	**AS21:103**
54	Kendall's S Frequency Distribution (F)	**AS21:345**
55	The Generalized Mann-Whitney U Statistic (PL1)	**AS21:348**
56	Permutational Significance Testing (A60)	**AS22:112**
62	A Generator for the Sampling Distribution of the Mann-Whitney U Statistic (F)	**AS22:269**
67	The Evaluation of Absorption Probabilities in Sequential Binomial Sampling (F)	**AS23:83**
68	A Program for Estimating the Parameters of the Truncated Negative Binomial Distribution (F)	**AS23:87**
71	The Upper Tail Probabilities of Kendall's Tau (F)	**AS23:98**
80	Spherical Statistics (A60)	**AS24:144**
81	Circular Statistics (A60)	**AS24:147**
84	Measures of Multivariate Skewness and Kurtosis (F)	**AS24:262**
85	Critical Values of the Sign Test (A60)	**AS24:265**
90	One-sided Multi-variable Inference (F)	**AS24:380**
92	The Sample Size for a Distribution-free Tolerance Interval (F)	**AS24:388**
93	A Generator for the Null Distribution of the Ansari-Bradley W Statistic (F)	**AS25:75**
95	Maximum-likelihood Estimation of Location and Scale Parameters from Grouped Data (F)	**AS25:88**
98	The Spectral Test for the Evaluation of Congruential Pseudo-random Generators (F)	**AS25:173** AS25:324 AS27:375
100	Normal-Johnson and Johnson-Normal Transformations (F)	**AS25:190** AS30:106 AS32:345
107	Operating Characteristics and Average Sampling Number for a General Class of Sequential Sampling Plans (F)	**AS26:98**

114	Computing the Numerator of Ordinal Measures of Association when the Data are Ordered Categories (F)	**AS26:211**
122	Weights for One-sided Multivariate Inference (F)	**AS27:100** AS30:352
124	Sample Sizes for One-sided and Strong Two-sided Distribution-free Tolerance Limits (A60)	**AS27:188**
138	Maximum Likelihood Estimation from Confined and Censored Normal Data (F)	**AS28:185**
146	Construction of Joint Probability of Selection for Systematic P.P.S. Sampling (F)	**AS29:107**
148	The Jackknife (F)	**AS29:115** AS35:89
157	The Runs-Up and Runs-Down Tests (F)	**AS30:81**
162	Multivariate Conditional Logistic Analysis of Stratum-matched Case-control Studies (F)	**AS30:190** AS33:123
171	Fisher's Exact Variance Test for the Poisson Distribution (F)	**AS31:67**
174	Multivariate Multisample Non-Parametric Tests (F)	**AS31:80**
176	Kernel Density Estimation using the Fast Fourier Transform (F)	**AS31:93** AS33:120 AS35:235
181	The W Test for Normality (F)	**AS31:176** AS32:224 AS35:232
188	Estimation of the Order of Dependence in Sequences (F)	**AS32:185**
189	Maximum Likelihood Estimation of the Parameters of the Beta Binomial Distribution (F)	**AS32:196**
193	A Revised Algorithm for the Spectral Test (F)	**AS32:328** AS34:102
202	Data-based Non-parametric Hazard Estimation (F)	**AS33:248**
203	Maximum Likelihood Estimation of Mixtures of Distributions (A60)	**AS33:327**
214	Calculation of Monte Carlo Confidence Intervals (F)	**AS34:296**
215	Maximum-likelihood Estimation of the Parameters of the Generalized Extreme-value Distribution (F)	**AS34:301** AS38:198
217	Computation of the Dip Statistic to Test for Unimodality (F)	**AS34:320**
218	Elements of the Fisher Information Matrix for the Smallest Extreme Value Distribution and Censored Data (F)	**AS35:80**
221	Maximum Likelihood Estimation of a Mixing Distribution (F)	**AS35:302** AS39:176
248	Empirical Distribution Function Goodness-of-fit Tests (F)	**AS38:535**
249	Evaluation of the Mean and Covariance of the Truncated Multinormal Distribution (F)	**AS38:543**
250	Tests of the Equality of Dispersion Matrices (F)	**AS38:553**
254	Maximum Likelihood Estimation from Grouped and Truncated Data with Finite Normal Mixture Models (F)	**AS39:273**
259	Estimating Confidence Intervals by the Robbins-Monro Search Process (F)	**AS39:413**
262	A Two-sample Test for Incomplete Multivariate Data (F)	**AS40:202**
266	Maximum Likelihood Estimation of the Parameters of the Dirichlet Distribution (F)	**AS40:365**

L5 : Function evaluation *(search also class C)*

3	The Integral of Student's t-distribution (F)	**AS17:189** AS18:118
4	An Auxiliary Function for Distribution Integrals (F)	**AS17:190** AS18:118 AS19:204 AS22:428
5	The Integral of the Non-central t-distribution (F)	**AS17:193** AS18:118 AS22:428 AS34:102
17	The Reciprocal of Mill's Ratio (A60)	**AS18:115**
27	The Integral of Student's t-distribution (A60)	**AS19:113**
33	Calculation of Hypergeometric Sample Sizes (F)	**AS19:287**
59	Hypergeometric Probabilities (F)	**AS22:130**
76	An Integral Useful in Calculating Non-central t and Bivariate Normal Probabilities (F)	**AS23:455** AS27:379 AS28:113 AS28:113 AS28:336 AS34:100 AS35:310 AS38:580
77	Null Distribution of the Largest Root Statistic (F)	**AS23:458**
86	The von Mises Distribution Function (A60)	**AS24:268**
89	The Upper Tail Probabilities of Spearman's *Rho* (F)	**AS24:377**
91	The Percentage Points of the χ^2 Distribution (F)	**AS24:385** AS40:233
106	The Distribution of Non-negative Quadratic Forms in Normal Variables (F)	**AS26:92** AS33:366
118	Approximate Rankits (F)	**AS26:362**
126	Probability Integral of the Normal Range (F)	**AS27:197** AS31:99
128	Approximating the Covariance Matrix of Normal Order Statistics (F)	**AS27:206** AS37:151
145	Exact Distribution of the Largest Multinomial Frequency (F)	**AS28:333**
152	Cumulative Hypergeometric Probabilities (F)	**AS29:221** AS31:339 AS38:199 AS40:374
153	Pan's Procedure for the Tail Probabilities of the Durbin-Watson Statistic (A60)	**AS29:224** AS30:189 AS33:363 AS33:366
155	The Distribution of a Linear Combination of χ^2 Random Variables (A60)	**AS29:323** AS33:366
158	Calculation of the Probabilities $\{P(l,k)\}$ for the Simply Ordered Alternative (F)	**AS30:85**
170	Computation of Probability and Non-centrality Parameter of a Non-central Chi-squared Distribution (F)	**AS30:349**
177	Expected Normal Order Statistics (Exact and Approximate) (F)	**AS31:161** AS32:223
184	Non-central Studentized Maximum and Related Multiple-t Probabilities (F)	**AS31:309**
190	Probabilities and Upper Quantiles for the Studentized Range (F)	**AS32:204** AS34:104 AS36:119
192	Approximate Percentage Points using Pearson Curves (F)	**AS32:322**
200	Approximating the Sum of Squares of Normal Scores (F)	**AS33:242**
204	The Distribution of a Positive Linear Combination of χ^2 Random Variables (A60)	**AS33:332**
209	The Distribution Function of Skewness and Kurtosis (F)	**AS34:87**

231	The Distribution of a Noncentral χ^2 Variable with Nonnegative Degrees of Freedom (P)	**AS36:402** AS38:204
234	Approximating the Percentage Points of Simple Linear Rank Statistics with Cornish-Fisher Expansions (F)	**AS37:278**
243	Cumulative Distribution Function of the Non-central t Distribution (F)	**AS38:185**
251	Multivariate Normal Probability Integrals with Product Correlation Structure (F)	**AS38:564**
256	The Distribution of a Quadratic Form in Normal Variables (P)	**AS39:294**
260	Evaluation of the Distribution of the Square of the Sample Multiple-correlation Coefficient (F)	**AS40:195**
261	Quantiles of the Distribution of the Square of the Sample Multiple-correlation Coefficient (F)	**AS40:199**

L6 : Random number generation

53	Wishart Variate Generator (F)	**AS21:341**
127	Generation of Random Orthogonal Matrices (F)	**AS27:199** AS31:190
134	The Generation of Beta Random Variables with one Parameter Greater than and one Parameter Less than 1 (F)	**AS28:90**
137	Simulating Spatial Patterns: Dependent Samples from a Multivariate Density (F)	**AS28:109**
144	Random $R \times C$ Tables with Given Row and Column Totals (F)	**AS28:329**
159	An Efficient Method of Generating Random $R \times C$ Tables with Given Row and Column Totals (F)	**AS30:91**
183	An Efficient and Portable Pseudo-random Number Generator (F)	**AS31:188** AS33:123 AS34:198 AS35:89
205	Enumeration of $R \times C$ Tables with Repeated Row Totals (F)	**AS33:340** AS35:88
213	Generation of Population Correlation Matrices with Specified Eigenvalues (F)	**AS34:193**
236	Recursive Enumeration of $R \times C$ Tables for Exact Likelihood Evaluation (P)	**AS37:290**

L7 : Analysis of variance (including analysis of covariance)

8	Main Effects from a Multi-way Table (F)	**AS17:277**
9	Construction of Additive Table (F)	**AS17:279**
19	Analysis of Variance for a Factorial Table (A60)	**AS18:199**
22	The Interaction Algorithm (F)	**AS18:283**
23	Calculation of Effects (A60)	**AS18:287**
25	Classification of Means from Analysis of Variance (F)	**AS18:294**
65	Interpreting Structure Formulae (F)	**AS22:414** AS39:167
72	Computing Mean Vectors and Dispersion Matrices in Multivariate Analysis of Variance (F)	**AS23:234**
104	BLUS Residuals (A60)	**AS25:317**

120	A Fortran Algorithm for the Additive Model in a Two-way Unbalanced MANOVA (F)	**AS27:92**
139	Maximum Likelihood Estimation in a Linear Model from Confined and Censored Normal Data (F)	**AS28:195** AS29:228 AS30:105
156	Combining Two Component Designs to form a Row-and-Column Design (F)	**AS29:334**
166	Generation of Polynomial Contrasts for Incomplete Factorial Designs with Quantitative Levels (F)	**AS30:325**
167	Screening Algorithm for Experimental Designs with Quantitative Levels (F)	**AS30:334**
173	Direct Design Matrix Generation for Balanced Factorial Experiments (F)	**AS31:74**
216	Fitting Models with a Linear Part and Auxiliary Parameters (F)	**AS34:310**
224	Combining Component Designs to form a Design with Several Orthogonal Blocking Factors (F)	**AS36:228**
246	An Analysis of Variance Table for Repeated Measurements with Unknown Autoregressive Parameter (F)	**AS38:402**

L8 : Regression *(search also classes D5, D6, D9, G, K)*

38	Best Subset Search (A60)	**AS20:112**
74	L_1-norm Fit of a Straight Line (F)	**AS23:244** AS25:96
75	Basic Procedures for Large, Sparse or Weighted Linear Least Squares Problems (A60)	**AS23:448** AS25:323 AS31:340
79	Gram–Schmidt Regression (A60)	**AS23:470**
108	Multiple Linear Regression with Minimum Sum of Absolute Errors (F)	**AS26:106** AS27:378 AS36:118
110	L_p Norm Fit of a Straight Line (F)	**AS26:114** AS28:112
132	Least Absolute Value Estimates for a Simple Linear Regression Problem (F)	**AS27:363**
135	Min-Max Estimates for a Linear Multiple Regression Problem (F)	**AS28:93** AS32:345
141	Inversion of a Symmetric Matrix in Regression Models (F)	**AS28:214** AS28:336 AS30:356
163	A Givens Algorithm for Moving from one Linear Model to another without going back to the Data (F)	**AS30:198**
178	The Gauss-Jordan Sweep Operator with Detection of Collinearity (F)	**AS31:166** AS38:420
206	Isotonic Regression in Two Independent Variables (F)	**AS33:352** AS35:312 AS36:120
211	The F-G Diagonalization Algorithm (F)	**AS34:177** AS37:147 AS37:317
212	Fitting the Exponential Curve by Least Squares (F)	**AS34:183**
223	Optimum Ridge Parameter Selection (F)	**AS36:112**
229	Computing Regression Quantiles (F)	**AS36:383**
238	A Simple Recursive Procedure for the L_1 Norm Fitting of a Straight Line (P)	**AS37:457**

257	Isotonic Regression for Umbrella Orderings (F)	**AS39:397**
268	All Possible Subset Regressions using the QR Decomposition (F)	**AS40:502**

L9 : Categorical data analysis

36	Exact Confidence Limits for the Odds Ratio in a 2×2 Table (F)	**AS20:105**
51	Log-linear Fit for Contingency Tables (F)	**AS21:218** AS25:193
87	Calculation of the Polychoric Estimate of Correlation in Contingency Tables (F)	**AS24:272** AS26:121
112	Exact Distributions derived from Two-way Tables (F)	**AS26:199** AS27:109 AS30:106 AS35:86
115	Exact Two-sided Confidence Limits for the Odds Ratio in a 2×2 Table (F)	**AS26:214**
116	The Tetrachoric Correlation and its Asymptotic Standard Error (F)	**AS26:343**
129	The Power Function of the ‘Exact’ Test for Comparing Two Binomial Distributions (F)	**AS27:212** AS29:118 AS30:108
142	Exact Tests of Significance in Binary Regression Models (F)	**AS28:319**
160	Partial and Marginal Association in Multidimensional Contingency Tables (F)	**AS30:97**
161	Critical Regions of an Unconditional Non-randomized Test of Homogeneity in 2×2 Contingency Tables (F)	**AS30:182**
185	Automatic Model Selection in Contingency Tables (F)	**AS31:317** AS40:376
201	Combined Significance Test of Differences Between Conditions and Ordinal Predictions (F)	**AS33:245**
207	Fitting a General Log-Linear Model (F)	**AS33:358**
244	Decomposability and Collapsibility for Log-linear Models (P)	**AS38:189**
247	Updating the Sufficient Configurations for Fitting ZPA Models to Multidimensional Contingency Tables (P)	**AS38:412**
252	Generating Classes for Log-linear Models (F)	**AS39:143**
253	Maximum Likelihood Estimation of the $RC(M)$ Association Model (F)	**AS39:152**
255	Fitting of Two-way Tables by Means for Rows, Columns and Cross-term (A60)	**AS39:283**

L10 : Time series analysis *(search also class J)*

73	Cross-spectrum Smoothing via the Finite Fourier Transform (F)	**AS23:238** AS30:354
150	Spectrum Estimate for a Counting Process (F)	**AS29:211**
151	Spectral Estimates for Bivariate Counting Processes by Sectioning the Data (F)	**AS29:214**
154	An Algorithm for Exact Maximum Likelihood Estimation of Autoregressive Moving Average Models by means of Kalman Filtering (F)	**AS29:311**
175	Cramér-Wold Factorization (F)	**AS31:86**
182	Finite Sample Prediction from ARIMA Processes (F)	**AS31:180**

191	An Algorithm for Approximate Likelihood Calculation of ARMA and Seasonal ARMA Models (F)	**AS32:211**
194	An Algorithm for Testing Goodness of Fit of *ARMA(P,Q)* Models (F)	**AS32:335**
197	A Fast Algorithm for the Exact Likelihood of Autoregressive Moving Average Models (F)	**AS33:104**
232	Computation of Population and Sample Correlation and Partial Correlation Matrices in *MARMA(P,Q)* Time Series (F)	**AS37:127**
237	The Corner Method for Identifying Autoregressive Moving Average Models (F)	**AS37:301**
242	The Exact Likelihood of a Vector Autoregressive Moving Average Model (F)	**AS38:161**

L12 : Discriminant analysis

165	An Algorithm to Construct a Discriminant Function in Fortran for Categorical Data (F)	**AS30:313**

L14 : Cluster analysis

15	Single Linkage Cluster Analysis (A60)	**AS18:106**
58	Euclidean Cluster Analysis (F)	**AS22:126** AS24:160
102	Ultrametric Distances for a Single Linkage Dendrogram (F)	**AS25:313**
113	A Transfer Algorithm for Non-hierarchical Classification (F)	**AS26:206**
136	A K-Means Clustering Algorithm (F)	**AS28:100** AS30:355
140	Clustering the Nodes of a Directed Graph (F)	**AS28:206**

L15 : Life testing, survival analysis

125	Maximum Likelihood Estimation for Censored Exponential Survival Data with Covariates (F)	**AS27:190** AS30:355
196	Conditional Multivariate Logistic Analysis of Stratified Case-control Studies (F)	**AS33:95**

M : Simulation, stochastic modelling *(search also classes L6 and L10)*

M2 : Queueing

230	Distribution of Customers in $M/E_T/m$ Queues using Hokstad's Approximation (F)	**AS36:394**
265	$G/G/1$ via Fast Fourier Transform (F)	**AS40:355**

M3 : Reliability

258	Average Run Lengths for Cumulative Sum Schemes (F)	**AS39:402**

N : Data handling *(search also class L2)*

N1 : Input, output

43	Variable Format in Fortran (F)	**AS20:213** AS20:346
57	Printing Multidimensional Tables (F)	**AS22:118**
264	Printing of Bit Patterns (F)	**AS40:229**

N4 : Storage management (e.g., stacks, heaps, trees)

1	Simulating Multidimensional Arrays in One Dimension (A60)	**AS17:180** AS18:116
20	The Efficient Formation of a Triangular Array with Restricted Storage for Data (F)	**AS18:203**
39	Arrays with a Variable Number of Dimensions (A60)	**AS20:115**
172	Direct Simulation of Nested Fortran *DO-LOOPS* (F)	**AS31:71**
219	Height Balanced Trees (F)	**AS35:220**

N6 : Sorting

26	Ranking an Array of Numbers (A60)	**AS19:111** AS22:133

N8 : Permuting

28	Transposing Multiway Structures (A60)	**AS19:115**

Z : Other

69	Knox Test for Space-Time Clustering in Epidemiology (F)	**AS23:92**
99	Fitting Johnson Curves by Moments (F)	**AS25:180** AS30:106
105	Fitting a Covariance Selection Model to a Matrix (F)	**AS26:88**
149	Amalgamation of Means in the Case of Simple Ordering (F)	**AS29:209**
198	The Level Probabilities of Order Restricted Inference (F)	**AS33:115**
199	A Branch and Bound Algorithm for Determining the Optimal Feature Subset of Given Size (F)	**AS33:236** AS35:314 AS40:376
208	Fitting a Multivariate Logistic Normal Distribution by the Method of Moments (F)	**AS34:81**
210	Fitting Five Parameter Johnson S_B Curves by Moments (F)	**AS34:95**
220	Operating Characteristics of James-Stein and Efron-Morris Estimators (F)	**AS35:226**
233	An Improved Branch and Bound Algorithm for Feature Subset Selection (F)	**AS37:139**

Chapter 3

Full GAMS Classification

This table provides the full classification given to each algorithm, only the first two fields were used to generate the index in Chapter 2.

AS	GAMS	AS	GAMS	AS	GAMS	AS	GAMS
1	N4	36	L9a	71	L4b1b	106	L5b1n
2	C8a	37	D2	72	L7e	107	L4a1a2
3	L5a1t	38	L8c1a2	73	L10b3a4	108	L8c3
4	L5a1	39	N4	74	L8a2	109	C7f
5	L5a1	40	G2d2	75	L8c1	110	L8a2
6	D2b1	41	L1c1b	76	L5a1	111	C8a
7	D2b1	42	C3a	77	L5b1	112	L9b
8	L7d	43	N1	78	L1c1	113	L14a1b
9	L7d	44	L3b4a	79	L8c1b1	114	L4b1b
10	C3a	45	L3a1	80	L4b1a4	115	L9a
11	D1b	46	D5	81	L4a1a2	116	L9a
12	L1c1b	47	G1b1a	82	D3a1	117	J1a
13	G2d2	48	L4a1d	83	J1a2	118	L5a2n
14	G2d2	49	L4a1d	84	L4c1a	119	L1c1d
15	L14a1a1	50	L4b3	85	L4a1b1	120	L7e
16	L1a3	51	L9c	86	L5a1v	121	C7d
17	L5a1n	52	L1a1	87	L9b	122	L4c1a
18	L1c1d	53	L6b3	88	C1	123	C7b
19	L7d1	54	L4b1b	89	L5a2	124	L4a1b
20	N4	55	L4b1b	90	L4c1a	125	L15
21	L3a	56	L4b1b	91	L5a2c	126	L5a1n
22	L7d1	57	N1	92	L4a1b	127	L6b15
23	L7d1	58	L14a1a	93	L4b1b	128	L5a2n
24	C8a	59	L5a1h	94	C1	129	L9a
25	L7a1	60	D4a1	95	L4a3	130	L3b4a
26	N6a1b	61	L3a3	96	L3	131	L1a1d
27	L5a1t	62	L4b1b	97	J1a1	132	L8a2
28	N8	63	C7f	98	L4a1d	133	G1a1a
29	L4a1d	64	C7f	99	Z	134	L6a2
30	L3a2	65	L7	100	L4a1a2	135	L8c3
31	L4a1a2b	66	C8a	101	L1	136	L14a1
32	C7e	67	L4a1a2b	102	L14a1a2	137	L6b
33	L5a1h	68	L4a1a2n	103	C7c	138	L4a1a2n
34	D2b1	69	Z	104	L7d3	139	L7d3
35	L4a4	70	C8a	105	Z	140	L14a1b

AS	GAMS	AS	GAMS	AS	GAMS	AS	GAMS
141	L8i	176	L4a1b2	211	L8i	246	L7b
142	L9b	177	L5a2n	212	L8e1b3	247	L9c
143	L1c1	178	L8i	213	L6b3	248	L4a1a4
144	L6b3	179	C1	214	L4a1b	249	L4c1a
145	L5a1	180	L1a1b	215	L4a1a4	250	L4c1b
146	L4a4	181	L4a1a4n	216	L7d3	251	L5b1n
147	C7e	182	L10a2d3	217	L4a1b1	252	L9c
148	L4a1b	183	L6a21	218	L4a1a4	253	L9b
149	Z	184	L5b1	219	N4	254	L4a1a4n
150	L10a3a3	185	L9c	220	Z	255	L9d
151	L10b3a3	186	J1a1	221	L4a1b2	256	L5b1n
152	L5a1b	187	C7e	222	K5	257	L8a1a2
153	L5a1	188	L4a1d	223	L8e2	258	M3a
154	L10a2e	189	L4a1a4b	224	L7d2	259	L4a1b
155	L5a1c	190	L5a1	225	K1a2a	260	L5a1b
156	L7f	191	L10a2d	226	C7b	261	L5a1b
157	L4a1d	192	L5a2	227	C1	262	L4c1b
158	L5a1	193	L4a1d	228	K1b2a	263	G2d2
159	L6b3	194	L10a2d1	229	L8c3	264	N1
160	L9	195	C8a	230	M2	265	M2
161	L9a	196	L15	231	L5a1c	266	L4c1a
162	L4c1a	197	L10a2d	232	L10c	267	L2c
163	L8i	198	Z	233	Z	268	L8c1a3
164	K1a2a	199	Z	234	L5a2		
165	L12	200	L5a2n	235	L1a1d		
166	L7d2	201	L9d	236	L6b3		
167	L7d	202	L4a1b	237	L10a2d1		
168	L3	203	L4a1a4	238	L8a2		
169	L3b4a	204	L5a1c	239	C7e		
170	L5a1c	205	L6b3	240	L1c1b		
171	L4a1a2p	206	L8c1b	241	C8a		
172	N4	207	L9c	242	L10a2d1		
173	L7d1	208	Z	243	L5a1t		
174	L4c1b	209	L5a1	244	L9c		
175	L10a1c	210	Z	245	C7a		

Chapter 4

The GAMS index

In this chapter we reproduce the full GAMS index produced by Boisvert et al. [2]. We are indebted to Ron Boisvert for providing us with a machine readable copy of this index and for permission to reproduce it.

A	Arithmetic, error analysis
A1	Integer
A2	Rational
A3	Real
A3a	Standard precision
A3c	Extended precision
A3d	Extended range
A4	Complex
A4a	Standard precision
A4c	Extended precision
A4d	Extended range
A5	Interval
A5a	Real
A5b	Complex
A6	Change of representation
A6a	Type conversion
A6b	Base conversion
A6c	Decomposition, construction
A7	Sequences (e.g., convergence acceleration)
B	Number theory
C	Elementary and special functions *(search also class L5)*
C1	Integer-valued functions (e.g., floor, ceiling, factorial, binomial coefficient, permutations, combinations)
C2	Powers, roots, reciprocals
C3	Polynomials
C3a	Orthogonal
C3a1	Trigonometric
C3a2	Chebyshev, Legendre
C3a3	Laguerre
C3a4	Hermite
C3b	Non-orthogonal
C4	Elementary transcendental functions
C4a	Trigonometric, inverse trigonometric
C4b	Exponential, logarithmic
C4c	Hyperbolic, inverse hyperbolic
C4d	Integrals of elementary transcendental functions
C5	Exponential and logarithmic integrals
C6	Cosine and sine integrals
C7	Gamma
C7a	Gamma, log gamma, reciprocal gamma
C7b	Beta, log beta
C7c	Psi function
C7d	Polygamma function
C7e	Incomplete gamma
C7f	Incomplete beta
C7g	Riemann zeta
C8	Error functions
C8a	Error functions, their inverses, integrals, including the normal distribution function
C8b	Fresnel integrals
C8c	Dawson's integral
C9	Legendre functions
C10	Bessel functions
C10a	J, Y, H_1, H_2

C10a1 Real argument, integer order
C10a2 Complex argument, integer order
C10a3 Real argument, real order
C10a4 Complex argument, real order
C10a5 Complex argument, complex order
C10b I, K
C10b1 Real argument, integer order
C10b2 Complex argument, integer order
C10b3 Real argument, real order
C10b4 Complex argument, real order
C10b5 Complex argument, complex order
C10c Kelvin functions
C10d Airy and Scorer functions
C10e Struve, Anger, and Weber functions
C10f Integrals of Bessel functions
C11 Confluent hypergeometric functions
C12 Coulomb wave functions
C13 Jacobian elliptic functions, theta functions
C14 Elliptic integrals
C15 Weierstrass elliptic functions
C16 Parabolic cylinder functions
C17 Mathieu functions
C18 Spheroidal wave functions
C19 Other special functions

D Linear Algebra

D1 Elementary vector and matrix operations
D1a Elementary vector operations
D1a1 Set to constant
D1a2 Minimum and maximum components
D1a3 Norm
D1a3a L_1 (sum of magnitudes)
D1a3b L_2 (Euclidean norm)
D1a3c L_∞ (maximum magnitude)
D1a4 Dot product (inner product)
D1a5 Copy or exchange (swap)
D1a6 Multiplication by scalar
D1a7 Triad ($\alpha x + y$ for vectors x, y and scalar α)
D1a8 Elementary rotation (Givens transformation)
D1a9 Elementary reflection (Householder transformation)
D1a10 Convolutions
D1a11 Other vector operations
D1b Elementary matrix operations
D1b1 Set to zero, to identity
D1b2 Norm
D1b3 Transpose
D1b4 Multiplication by vector
D1b5 Addition, subtraction
D1b6 Multiplication
D1b7 Matrix polynomial
D1b8 Copy
D1b9 Storage mode conversion
D1b10 Elementary rotation (Givens transformation)
D1b11 Elementary reflection (Householder transformation)
D2 Solution of systems of linear equations (including inversion, LU and related decompositions)

D2a	Real nonsymmetric matrices
D2a1	General
D2a2	Banded
D2a2a	Tridiagonal
D2a3	Triangular
D2a4	Sparse
D2b	Real symmetric matrices
D2b1	General
D2b1a	Indefinite
D2b1b	Positive definite
D2b2	Positive definite banded
D2b2a	Tridiagonal
D2b4	Sparse
D2c	Complex non-Hermitian matrices
D2c1	General
D2c2	Banded
D2c2a	Tridiagonal
D2c3	Triangular
D2c4	Sparse
D2d	Complex Hermitian matrices
D2d1	General
D2d1a	Indefinite
D2d1b	Positive definite
D2d2	Positive definite banded
D2d2a	Tridiagonal
D2d4	Sparse
D2e	Associated operations (e.g., matrix reorderings)
D3	Determinants
D3a	Real nonsymmetric matrices
D3a1	General
D3a2	Banded
D3a2a	Tridiagonal
D3a3	Triangular
D3a4	Sparse
D3b	Real symmetric matrices
D3b1	General
D3b1a	Indefinite
D3b1b	Positive definite
D3b2	Positive definite banded
D3b2a	Tridiagonal
D3b4	Sparse
D3c	Complex non-Hermitian matrices
D3c1	General
D3c2	Banded
D3c2a	Tridiagonal
D3c3	Triangular
D3c4	Sparse
D3d	Complex Hermitian matrices
D3d1	General
D3d1a	Indefinite
D3d1b	Positive definite
D3d2	Positive definite banded
D3d2a	Tridiagonal
D3d4	Sparse
D4	Eigenvalues, eigenvectors
D4a	Ordinary eigenvalue problems ($Ax = \lambda x$)
D4a1	Real symmetric

D4a2	Real nonsymmetric
D4a3	Complex Hermitian
D4a4	Complex non-Hermitian
D4a5	Tridiagonal
D4a6	Banded
D4a7	Sparse
D4b	Generalized eigenvalue problems (e.g., $Ax = \lambda Bx$)
D4b1	Real symmetric
D4b2	Real general
D4b3	Complex Hermitian
D4b4	Complex general
D4b5	Banded
D4c	Associated operations
D4c1	Transform problem
D4c1a	Balance matrix
D4c1b	Reduce to compact form
D4c1b1	Tridiagonal
D4c1b2	Hessenberg
D4c1b3	Other
D4c1c	Standardize problem
D4c2	Compute eigenvalues of matrix in compact form
D4c2a	Tridiagonal
D4c2b	Hessenberg
D4c2c	Other
D4c3	Form eigenvectors from eigenvalues
D4c4	Back transform eigenvectors
D4c5	Determine Jordan normal form
D5	QR decomposition, Gram-Schmidt orthogonalization
D6	Singular value decomposition
D7	Update matrix decompositions
D7a	LU
D7b	Cholesky
D7c	QR
D7d	Singular value
D8	Other matrix equations (e.g., $AX + XB = C$)
D9	Singular, overdetermined or underdetermined systems of linear equations, generalized inverses
D9a	Unconstrained
D9a1	Least squares (L_2) solution
D9a2	Chebyshev (L_∞) solution
D9a3	Least absolute value (L_1) solution
D9a4	Other
D9b	Constrained
D9b1	Least squares (L_2) solution
D9b2	Chebyshev (L_∞) solution
D9b3	Least absolute value (L_1)
D9b4	Other
D9c	Generalized inverses
E	Interpolation
E1	Univariate data (curve fitting)
E1a	Polynomial splines (piecewise polynomials)
E1b	Polynomials
E1c	Other functions (e.g., rational, trigonometric)
E2	Multivariate data (surface fitting)
E2a	Gridded

E2b	Scattered
E3	Service routines for interpolation
E3a	Evaluation of fitted functions, including quadrature
E3a1	Function evaluation
E3a2	Derivative evaluation
E3a3	Quadrature
E3b	Grid or knot generation
E3c	Manipulation of basis functions (e.g., evaluation, change of basis)
E3d	Other
F	Solution of nonlinear equations
F1	Single equation
F1a	Polynomial
F1a1	Real coefficients
F1a2	Complex coefficients
F1b	Nonpolynomial
F2	System of equations
F3	Service routines (e.g., check user-supplied derivatives)
G	Optimization *(search also classes K, L8)*
G1	Unconstrained
G1a	Univariate
G1a1	Smooth function
G1a1a	User provides no derivatives
G1a1b	User provides first derivatives
G1a1c	User provides first and second derivatives
G1a2	General function (no smoothness assumed)
G1b	Multivariate
G1b1	Smooth function
G1b1a	User provides no derivatives
G1b1b	User provides first derivatives
G1b1c	User provides first and second derivatives
G1b2	General function (no smoothness assumed)
G2	Constrained
G2a	Linear programming
G2a1	Dense matrix of constraints
G2a2	Sparse matrix of constraints
G2b	Transportation and assignments problem
G2c	Integer programming
G2c1	Zero/one
G2c2	Covering and packing problems
G2c3	Knapsack problems
G2c4	Matching problems
G2c5	Routing, scheduling, location problems
G2c6	Pure integer programming
G2c7	Mixed integer programming
G2d	Network (for network reliability search class M)
G2d1	Shortest path
G2d2	Minimum spanning tree
G2d3	Maximum flow
G2d3a	Generalized networks
G2d3b	Networks with side constraints
G2d4	Test problem generation
G2e	Quadratic programming
G2e1	Positive definite Hessian (i.e., convex problem)

G2e2	Indefinite Hessian
G2f	Geometric programming
G2g	Dynamic programming
G2h	General nonlinear programming
G2h1	Simple bounds
G2h1a	Smooth function
G2h1a1	User provides no derivatives
G2h1a2	User provides first derivatives
G2h1a3	User provides first and second derivatives
G2h1b	General function (no smoothness assumed)
G2h2	Linear equality or inequality constraints
G2h2a	Smooth function
G2h2a1	User provides no derivatives
G2h2a2	User provides first derivatives
G2h2a3	User provides first and second derivatives
G2h2b	General function (no smoothness assumed)
G2h3	Nonlinear constraints
G2h3a	Equality constraints only
G2h3a1	Smooth function and constraints
G2h3a1a	User provides no derivatives
G2h3a1b	User provides first derivatives of function and constraints
G2h3a1c	User provides first and second derivatives of function and constraints
G2h3a2	General function and constraints (no smoothness assumed)
G2h3b	Equality and inequality constraints
G2h3b1	Smooth function and constraints
G2h3b1a	User provides no derivatives
G2h3b1b	User provides first derivatives of function and constraints
G2h3b1c	User provides first and second derivatives of function and constraints
G2h3b2	General function and constraints (no smoothness assumed)
G2i	Global solution to nonconvex problems
G3	Optimal control
G4	Service routines
G4a	Problem input (e.g., matrix generation)
G4b	Problem scaling
G4c	Check user-supplied derivatives
G4d	Find feasible point
G4e	Check for redundancy
G4f	Other

H	Differentiation, integration

H1	Numerical differentiation
H2	Quadrature (numerical evaluation of definite integrals)
H2a	One-dimensional integrals
H2a1	Finite interval (general integrand)
H2a1a	Integrand available via user-defined procedure
H2a1a1	Automatic (user need only specify required accuracy)
H2a1a2	Nonautomatic
H2a1b	Integrand available only on grid
H2a1b1	Automatic (user need only specify required accuracy)
H2a1b2	Nonautomatic
H2a2	Finite interval (specific or special type integrand including weight functions, oscillating and singular integrands, principal value integrals, splines, etc.)
H2a2a	Integrand available via user-defined procedure
H2a2a1	Automatic (user need only specify required accuracy)

H2a2a2 Nonautomatic
H2a2b Integrand available only on grid
H2a2b1 Automatic (user need only specify required accuracy)
H2a2b2 Nonautomatic
H2a3 Semi-infinite interval (including exp $-x$ weight function)
H2a3a Integrand available via user-defined procedure
H2a3a1 Automatic (user need only specify required accuracy)
H2a3a2 Nonautomatic
H2a4 Infinite interval (including exp $-x^2$ weight function)
H2a4a Integrand available via user-defined procedure
H2a4a1 Automatic (user need only specify required accuracy)
H2a4a2 Nonautomatic
H2b Multidimensional integrals
H2b1 One or more hyper-rectangular regions (includes iterated integrals)
H2b1a Integrand available via user-defined procedure
H2b1a1 Automatic (user need only specify required accuracy)
H2b1a2 Nonautomatic
H2b1b Integrand available only on grid
H2b1b1 Automatic (user need only specify required accuracy)
H2b1b2 Nonautomatic
H2b2 n-D quadrature on a nonrectangular region
H2b2a Integrand available via user-defined procedure
H2b2a1 Automatic (user need only specify required accuracy)
H2b2a2 Nonautomatic
H2b2b Integrand available only on grid
H2b2b1 Automatic (user need only specify required accuracy)
H2b2b2 Nonautomatic
H2c Service routines (e.g., compute weights and nodes for quadrature formulas)

I Differential and integral equations

I1 Ordinary differential equations (ODE's)
I1a Initial value problems
I1a1 General, nonstiff or mildly stiff
I1a1a One-step methods (e.g., Runge-Kutta)
I1a1b Multistep methods (e.g., Adams' predictor-corrector)
I1a1c Extrapolation methods (e.g., Bulirsch-Stoer)
I1a2 Stiff and mixed algebraic- differential equations
I1b Multipoint boundary value problems
I1b1 Linear
I1b2 Nonlinear
I1b3 Eigenvalue (e.g., Sturm-Liouville)
I1c Service routines (e.g., interpolation of solutions, error handling, test programs)
I2 Partial differential equations
I2a Initial boundary value problems
I2a1 Parabolic
I2a1a One spatial dimension
I2a1b Two or more spatial dimensions
I2a2 Hyperbolic
I2b Elliptic boundary value problems
I2b1 Linear
I2b1a Second order
I2b1a1 Poisson (Laplace) or Helmholtz equation
I2b1a1a Rectangular domain (or topologically rectangular in the coordinate system)

I2b1a1b Nonrectangular domain
I2b1a2 Other separable problems
I2b1a3 Nonseparable problems
I2b1c Higher order equations (e.g., biharmonic)
I2b2 Nonlinear
I2b3 Eigenvalue
I2b4 Service routines
I2b4a Domain triangulation *(search also class P2a2c1)*
I2b4b Solution of discretized elliptic equations
I3 Integral equations

J Integral transforms

J1 Trigonometric transforms including Fast Fourier transforms
J1a One-dimensional
J1a1 Real
J1a2 Complex
J1a3 Sine and cosine transforms
J1b Multidimensional
J2 Convolutions
J3 Laplace transforms
J4 Hilbert transforms

K Approximation *(search also class L8)*

K1 Least squares (L_2) approximation
K1a Linear least squares *(search also classes D5, D6, D9)*
K1a1 Unconstrained
K1a1a Univariate data (curve fitting)
K1a1a1 Polynomial splines (piecewise polynomials)
K1a1a2 Polynomials
K1a1a3 Other functions (e.g., rational, trigonometric, user-specified)
K1a1b Multivariate data (surface fitting)
K1a2 Constrained
K1a2a Linear constraints
K1a2b Nonlinear constraints
K1b Nonlinear least squares
K1b1 Unconstrained
K1b1a Smooth functions
K1b1a1 User provides no derivatives
K1b1a2 User provides first derivatives
K1b1a3 User provides first and second derivatives
K1b1b General functions
K1b2 Constrained
K1b2a Linear constraints
K1b2b Nonlinear constraints
K2 Minimax (L_∞) approximation
K3 Least absolute value (L_1) approximation
K4 Other analytic approximations (e.g., Taylor polynomial, Pade)
K5 Smoothing
K6 Service routines for approximation
K6a Evaluation of fitted functions, including quadrature
K6a1 Function evaluation
K6a2 Derivative evaluation
K6a3 Quadrature
K6b Grid or knot generation
K6c Manipulation of basis functions (e.g., evaluation, change of basis)

K6d	Other
L	Statistics, probability
L1	Data summarization
L1a	One-dimensional data
L1a1	Raw data
L1a1a	Location
L1a1b	Dispersion
L1a1c	Shape
L1a1d	Frequency, cumulative frequency
L1a1e	Ties
L1a3	Grouped data
L1b	Two dimensional data *(search also class L1c)*
L1c	Multi-dimensional data
L1c1	Raw data
L1c1b	Covariance, correlation
L1c1d	Frequency, cumulative frequency
L1c2	Raw data containing missing values *(search also class L1c1)*
L2	Data manipulation
L2a	Transform *(search also classes L10a, N6, and N8)*
L2b	Tally data
L2c	Subset
L2d	Merge *(search also class N7)*
L2e	Construct new variables (e.g., indicator variables)
L3	Elementary statistical graphics *(search also class Q)*
L3a	One-dimensional data
L3a1	Histograms
L3a2	Frequency, cumulative frequency, percentile plots
L3a3	EDA (e.g., box-plots, stem-and-leaf plots)
L3a4	Bar charts
L3a5	Pie charts
L3a6	X_i vs. i (including symbol plots)
L3a7	Lag plots (e.g., plots of X_i vs. X_{i-1})
L3b	Two-dimensional data *(search also class L3e)*
L3b1	Histograms (superimposed and bivariate)
L3b2	Frequency, cumulative frequency
L3b3	EDA
L3b4	Scatter diagrams
L3b4a	Y vs. X
L3b4b	Symbol plots
L3b4c	Lag plots (i.e., plots of X_i vs. Y_{i-j})
L3c	Three-dimensional data *(search also class L3e)*
L3e	Multi-dimensional data
L3e1	Histograms
L3e2	Frequency, cumulative frequency, percentile plots
L3e3	Scatter diagrams
L3e3a	Superimposed scatter diagrams of two or more Y-variables vs. one or more X-variables
L3e3c	Superimposed scatter diagrams of X_i vs. i for two or more X-variables
L3e3d	Matrices of bivariate scatter diagrams
L3e4	EDA
L4	Elementary data analysis
L4a	One-dimensional data
L4a1	Raw data
L4a1a	Parametric analysis

L4a1a1	Plots of empirical and theoretical density and distribution functions
L4a1a2	Parameter estimates and hypothesis tests
L4a1a2b	Beta, binomial
L4a1a2c	Cauchy, chi-squared
L4a1a2d	Double exponential
L4a1a2e	Exponential, extreme value type 1, extreme value type 2
L4a1a2f	F distribution
L4a1a2g	Gamma, geometric
L4a1a2h	Halfnormal
L4a1a2l	Lambda, logistic, lognormal
L4a1a2n	Negative binomial, normal
L4a1a2p	Pareto, Poisson
L4a1a2s	Semicircular
L4a1a2t	t distribution, triangular
L4a1a2u	Uniform
L4a1a2w	Weibull
L4a1a3	Probability plot correlation coefficient plots
L4a1a3c	Chi-squared
L4a1a3e	Extreme value type 2
L4a1a3g	Gamma, geometric
L4a1a3l	Lambda
L4a1a3n	Normal
L4a1a3p	Pareto, Poisson
L4a1a3t	t distribution
L4a1a3w	Weibull
L4a1a4	Parameter estimates and tests
L4a1a4b	Binomial
L4a1a4e	Extreme value
L4a1a4n	Normal
L4a1a4p	Poisson
L4a1a4u	Uniform
L4a1a4w	Weibull
L4a1a5	Transformation selection (e.g., for normality)
L4a1a6	Tail and outlier analysis
L4a1a7	Tolerance limits
L4a1b	Distribution-free (nonparametric) analysis
L4a1b1	Estimates and tests regarding location (e.g., median), dispersion, and shape
L4a1b2	Density function estimation
L4a1c	Goodness-of-fit tests
L4a1d	Analysis of a sequence of numbers *(search also class L10a)*
L4a3	Grouped (and/or censored) data
L4a4	Data sampled from a finite population
L4a5	Categorical data
L4b	Two dimensional data *(search also class L4c)*
L4b1	Pairwise independent data
L4b1a	Parametric analysis
L4b1a1	Plots of empirical and theoretical density and distribution functions
L4b1a4	Parameter estimates and hypothesis tests
L4b1b	Distribution-free analysis (e.g., tests based on ranks)
L4b1c	Goodness-of-fit tests
L4b3	Pairwise dependent data
L4b4	Pairwise dependent grouped data
L4b5	Data sampled from a finite population
L4c	Multi-dimensional data *(search also classes L4b and L7a1)*

L4c1 Independent samples
L4c1a Parametric analysis
L4c1b Distribution-free analysis (e.g., tests based on ranks)
L4e Multiple multi-dimensional data sets
L5 Function evaluation *(search also class C)*
L5a Univariate
L5a1 Cumulative distribution functions, probability density functions
L5a1b Beta, binomial
L5a1c Cauchy, chi-squared
L5a1d Double exponential
L5a1e Error function, exponential, extreme value
L5a1f F distribution
L5a1g Gamma, general, geometric
L5a1h Halfnormal, hypergeometric
L5a1k Kendall F statistic, Kolmogorov-Smirnov
L5a1l Lambda, logistic, lognormal
L5a1n Negative binomial, normal
L5a1p Pareto, Poisson
L5a1t t distribution
L5a1u Uniform
L5a1v Von Mises
L5a1w Weibull
L5a2 Inverse distribution functions, sparsity functions
L5a2b Beta, binomial
L5a2c Cauchy, chi-squared
L5a2d Double exponential
L5a2e Error function, exponential, extreme value
L5a2f F distribution
L5a2g Gamma, general, geometric
L5a2h Halfnormal
L5a2l Lambda, logistic, lognormal
L5a2n Negative binomial, normal, normal order statistics
L5a2p Pareto, Poisson
L5a2t t distribution
L5a2u Uniform
L5a2w Weibull
L5b Multivariate
L5b1 Cumulative multivariate distribution functions, probability density functions
L5b1n Normal
L5b2 Inverse cumulative distribution functions
L5b2n Normal
L6 Random number generation
L6a Univariate
L6a2 Beta, binomial, Boolean
L6a3 Cauchy, chi-squared
L6a4 Double exponential
L6a5 Exponential, extreme value
L6a6 F distribution
L6a7 Gamma, general (continuous, discrete), geometric
L6a8 Halfnormal, hypergeometric
L6a12 Lambda, logistic, lognormal
L6a14 Negative binomial, normal, normal order statistics
L6a16 Pareto, Pascal, permutations, Poisson
L6a19 Samples, stable distribution
L6a20 t distribution, time series, triangular
L6a21 Uniform (continuous, discrete), uniform order statistics

L6a22	Von Mises
L6a23	Weibull
L6b	Multivariate
L6b3	Contingency table, correlation matrix
L6b5	Experimental designs
L6b12	Discrete linear L_1 (least absolute value) approximation test problem
L6b13	Multinomial
L6b14	Normal
L6b15	Orthogonal matrix
L6b21	Uniform
L6c	Service routines (e.g., seed)
L7	Analysis of variance (including analysis of covariance)
L7a	One-way
L7a1	Parametric
L7a2	Distribution-free
L7b	Two-way *(search also class L7d)*
L7c	Three-way (e.g., Latin squares) *(search also class L7d)*
L7d	Multi-way
L7d1	Balanced complete data (equal number of observations in every cell, e.g., factorial designs)
L7d2	Balanced incomplete data (equal number of observations in cells containing data, e.g., fractional factorial designs)
L7d3	General linear models (unbalanced data)
L7e	Multivariate
L7f	Generate experimental designs
L7g	Service routines
L8	Regression *(search also classes D5, D6, D9, G, K)*
L8a	Simple linear (i.e., $y = b_0 + b_1 x$) *(search also class L8h)*
L8a1	Ordinary least squares
L8a1a	Parameter estimation
L8a1a1	Unweighted data
L8a1a2	Weighted data
L8a1c	Inference (e.g., calibration) *(search also class L8a1a)*
L8a2	L_p for p different from 2 (e.g., least absolute values, minimax)
L8a3	Robust least squares
L8a4	Errors in variables
L8b	Polynomial (e.g., $y = b_0 + b_1 x + b_2 x^2$) *(search also class L8c)*
L8b1	Ordinary least squares
L8b1a	Degree determination
L8b1b	Parameter estimation
L8b1b1	Not using orthogonal polynomials
L8b1b2	Using orthogonal polynomials
L8b1c	Analysis *(search also class L8b1b)*
L8b1d	Inference *(search also class L8b1b)*
L8c	Multiple linear (i.e., $y = b_0 + b_1 x_1 + \ldots + b_p x_p$)
L8c1	Ordinary least squares
L8c1a	Variable selection
L8c1a1	Using raw data
L8c1a2	Using correlation or covariance data
L8c1a3	Using other data
L8c1b	Parameter estimation *(search also class L8c1a)*
L8c1b1	Using raw data
L8c1b2	Using correlation data
L8c1c	Analysis *(search also classes L8c1a and L8c1b)*
L8c1d	Inference *(search also classes L8c1a and L8c1b)*

L8c2	Several multiple regressions
L8c3	L_p for p different from 2
L8c4	Robust least squares
L8c5	Measurement error models
L8c6	Models based on ranks
L8d	Polynomial in several variables analysis)
L8e	Nonlinear (i.e., $y = F(X, b)$) *(search also class L8h)*
L8e1	Ordinary least squares
L8e1a	Variable selection
L8e1b	Parameter estimation *(search also class L8e1a)*
L8e1b1	Unweighted data, user provides no derivatives
L8e1b2	Unweighted data, user provides derivatives
L8e1b3	Weighted data, user provides no derivatives
L8e1b4	Weighted data, user provides derivatives
L8e2	Ridge
L8e5	Measurement error models
L8f	Simultaneous (i.e., $Y = Xb + \varepsilon$)
L8g	Spline (i.e., piecewise polynomial)
L8h	EDA (e.g., smoothing)
L8i	Service routines (e.g., matrix manipulation for variable selection
L9	Categorical data analysis
L9a	2-by-2 tables
L9b	Two-way tables *(search also class L9d)*
L9c	Log-linear model
L9d	EDA (e.g., median polish)
L10	Time series analysis *(search also class J)*
L10a	Univariate *(search also classes L3a6 and L3a7)*
L10a1	Transformations
L10a1a	Elementary *(search also class L2a)*
L10a1b	Stationarity *(search also class L8a1)*
L10a1c	Filters *(search also class K5)*
L10a1c1	Difference filters (nonseasonal and seasonal)
L10a1c2	Symmetric linear filters (e.g., moving averages)
L10a1c3	Autoregressive linear
L10a1c4	Other
L10a1d	Taper
L10a2	Time domain analysis
L10a2a	Summary statistics
L10a2a1	Autocovariances and autocorrelations
L10a2a2	Partial autocorrelations
L10a2b	Stationarity analysis *(search also class L10a2a)*
L10a2c	Autoregressive models
L10a2c1	Model identification
L10a2c2	Parameter estimation
L10a2d	ARMA and ARIMA models (including Box-Jenkins methods)
L10a2d1	Model identification
L10a2d2	Parameter estimation
L10a2d3	Forecasting
L10a2e	State-space analysis (e.g., Kalman filtering)
L10a2f	Analysis of a locally stationary series
L10a3	Frequency domain analysis *(search also class J1)*
L10a3a	Spectral analysis
L10a3a1	Pilot analysis
L10a3a2	Periodogram analysis
L10a3a3	Spectrum estimation using the periodogram
L10a3a4	Spectrum estimation using the Fourier transform of the autocorrelation function

L10a3a5	Spectrum estimation using autoregressive models
L10a3a6	Spectral windows
L10a3b	Complex demodulation
L10b	Two time series *(search also classes L3b3c, L10c, and L10d)*
L10b2	Time domain analysis
L10b2a	Summary statistics (e.g., cross-correlations)
L10b2b	Transfer function models
L10b3	Frequency domain analysis *(search also class J1)*
L10b3a	Cross-spectral analysis
L10b3a2	Cross-periodogram analysis
L10b3a3	Cross-spectrum estimation using the cross-periodogram
L10b3a4	Cross-spectrum estimation using the Fourier transform of the cross-correlation or cross-covariance function
L10b3a6	Spectral functions
	Multivariate time series *(search also classes J1, L3e3 and*L10c
L10d	Two multi-channel time series
L11	Correlation analysis *(search also classes L4 and L13c)*
L12	Discriminant analysis
L13	Covariance structure models
L13a	Factor analysis
L13b	Principal components analysis
L13c	Canonical correlation
L14	Cluster analysis
L14a	One-way
L14a1	Unconstrained
L14a1a	Nested
L14a1a1	Joining (e.g., single link)
L14a1a2	Divisive
L14a1a3	Switching
L14a1a4	Predict missing values
L14a1b	Non-nested
L14a2	Constrained
L14b	Two-way
L14c	Display
L14d	Service routines (e.g., compute distance matrix)
L15	Life testing, survival analysis
L16	Multidimensional scaling
L17	Statistical data sets

M	Simulation, stochastic modelling *(search also classes L6 and L10)*
M1	Simulation
M1a	Discrete
M1b	Continuous (Markov models)
M2	Queueing
M3	Reliability
M3a	Quality control
M3b	Electrical network
M4	Project optimization (e.g., PERT)

N	Data handling *(search also class L2)*
N1	Input, output
N2	Bit manipulation
N3	Character manipulation
N4	Storage management (e.g., stacks, heaps, trees)
N5	Searching

N5a	Extreme value
N5b	Insertion position
N5c	On a key
N6	Sorting
N6a	Internal
N6a1	Passive (i.e. construct pointer array, rank)
N6a1a	Integer
N6a1b	Real
N6a1c	Character
N6a2	Active
N6a2a	Integer
N6a2b	Real
N6a2c	Character
N6b	External
N7	Merging
N8	Permuting

O	Symbolic computation
P	Computational geometry *(search also classes G and Q)*
Q	Graphics *(search also class L3)*
R	Service routines

R1	Machine-dependent constants
R2	Error checking (e.g., check monotonicity)
R3	Error handling
R3a	Set criteria for fatal errors
R3b	Set unit number for error messages
R3c	Other utilities
R4	Documentation retrieval

S	Software development tools

S1	Program transformation tools
S2	Static program analysis tools
S3	Dynamic program analysis tools

Z	Other

Appendix A

Availability of Data, Tools and Algorithm Sources

In addition to the Fortran code described in Appendix B there is a perl script for transforming the original database files into a number of more useful formats. Currently the perl script will generate

1. a BibTeXdatabase entry for each algorithm,
2. a cumulative index based on the SHARE classification like the one in [6],
3. a cumulative index based on the GAMS classification like the one in [7].

The algorithm databases available are

1. The CALGO algorithms published in Communications of the ACM from 1960–1975 and in ACM Transactions on Mathematical Software from 1975–,
2. The Applied Statistics algorithms published in Applied Statistics 1968–.

The databases and software are available via electronic mail or anonymous ftp from *unix.hensa.ac.uk*. The files are

- acm.dbase – the CALGO algorithms database,
- acm.bib – BibTeXdatabase of the CALGO algorithms,
- as.dbase – the Applied Statistics algorithms database,
- as.bib – BibTeXdatabase of the Applied Statistics algorithms,
- bibeg.f, lib.f, shared.f – Fortran 77 codes for operating on the database files. These codes are described in Appendix B,
- bibop.sh – a shar file containing the perl script, data files and man page as described above.

To obtain these files by electronic mail send mail of the form

```
send misc/netlib/bib/file
```

to archive@unix.hensa.ac.uk where file is replaced by the name of the file you require.

To obtain files via anonymous ftp, connect to unix.hensa.ac.uk (129.12.21.7) – the files are in the directory misc/netlib/bib. Compressed PostScript versions of [6] and [7] are also available for ftp in misc/ukc.reports/reports/64 and misc/ukc.reports/reports/71 respectively.

Please send bug reports, extensions to the perl script or further algorithm databases to trh@ukc.ac.uk.

Availability of algorithms

The sources to all algorithms published in TOMS and a number of those published in the Communications to the ACM are available via both e-mail and ftp.

To obtain copies via e-mail send a message of the form

`send number from apstat`

where number is the number of the algorithm you require, e.g., to obtain algorithm 276 the message would be

`send 276 from apstat`

to statlib@unix.hensa.ac.uk (UK/Europe) or statlib@temper.stat.cmu.edu (US).

Using anonymous ftp connect to unix.hensa.ac.uk (129.12.21.7) from the UK and Europe or lib.stat.cmu.edu (US) log in as anonymous to unix.hensa.ac.uk and statlib to lib.stat.cmu.edu. In both cases use your e-mail address as a password. To access the Applied Statistics algorithms `cd statlib/apstat` on unix.hensa.ac.uk and `cd apstat` on lib.stat.cmu.edu.

The algorithms currently available are

3, 5–7, 13–15, 22, 27, 30, 32, 34, 38, 40, 41, 45–47, 51–53, 57, 58, 60, 62–66, 75–78, 83, 84, 88, 89, 91, 93, 95, 97, 99, 100, 103, 107, 108, 109, 111, 114, 116, 117, 121, 123, 125–128, 132–136, 138–143, 145, 147–155, 157–202, 205–278.

Appendix B

A Remark on ACM TOMS Algorithm 620

We report on an enhanced version of the database originally reported in [10]. In this new version we have included all the information necessary to generate full bibliographic references. Extra information includes the author's name (including any accents), the page range of the original reference (rather than just the starting page), the month and year of publication and an abbreviated journal name. The programming language used to code the algorithm is also given. Any mathematical notation used within the algorithm title and accents in the author's name have been defined using TEX[8]. Following the practice used with BIBTEX[9], all letters within the title which need to remain capitalised in a printed version of the reference (e.g., Fortran, Bessel) are enclosed in braces.

The keywords and SHARE classification associated with each algorithm have been included with the main entry information rather than in a separate list as in [10]. Finally we have included references to all published remarks for each algorithm. These are in a compressed form which provides type (Remark or Certification), journal in which it appeared, volume, number, month and year of publication, page range and author.

The entry for each algorithm consists of either four or five records depending on whether there have been any published remarks. Each line in the file is restricted to 80 characters; records longer than this are continued on successive lines using a $+$ in the first character position to denote that the line is a continuation line. Only the first record begins in character position one.

The first record gives details of the primary reference. The second and third are the author's name and title of the algorithm respectively. The keywords make up the fourth record. The first four records are always present. The final record provides details of remarks; individual fields within each remark reference are separated by commas and a semicolon is used to terminate each reference. Multiple remark references are treated as a single record.

As an example, the following entry is for algorithm 487

```
487    cacm  703  704 17 12  December 1974 s14   F
 J. Pomeranz;
 Exact Cumulative Distribution of the {K}olmogorov-{S}mirnov Statistic for
+ Small Samples
 goodness-of-fit testing;k-s statistic;k-s test;Kolmogorov-Smirnov test;
 R,toms,111,2,1,March,1976,J. Pomeranz;
+R,toms,285--294,3,3,September,1977,R. Kallman;
```

The first line should be interpreted as 'ACM CALGO Algorithm 487 appeared in Commun. ACM, Volume 17, Number 12, December 1974, pages 703–704'. The algorithm was implemented in Fortran and the modified SHARE classification is S14 (a sub-classification of the Special Functions).

The title spans two lines and contains two letters which must remain in upper case. The second remark is interpreted as being a Remark which appeared in ACM TOMS, Volume 3, Number 3 (second of the threes) in September 1977, pages 285–294. The author was R. Kallman.

We have provided Fortran routines which read in a reference in this compressed form and split the information up into a number of variables stored in a pair of common blocks. A template showing how to use these routines is given in Figure B.1. The two common blocks CREFNO and CREFST,

```
*
*   TEMPLATE FOR USE OF GETREF
*
      LOGICAL GETREF
*
* Insert COMMON block definitions here
*
* Set up i/o channels and open data file
* (This routine contains a possibly machine dependent
*  OPEN statement)
     CALL SETUP
*
* Set up output file -- application dependent routine
     CALL OUTFIL
*
* Initialize input buffer for references
* a call to initrf must precede calls to getref
     CALL INITRF
*
* Process all references
  10 IF (GETREF()) THEN
*        process current reference
         GO TO 10
     END IF
*
*
```

Figure B.1: Template code for processing references

holding numerical and character data respectively, are defined by

```
      INTEGER NUMBER,PAGEND,PAGEST,VOLUME,YEAR
      COMMON /CREFNO/VOLUME,NUMBER,YEAR,PAGEST,PAGEND

      INTEGER AUTLEN,TITLEN,KEYLEN,OTHLEN
      PARAMETER (AUTLEN=80,TITLEN=160,KEYLEN=400
     +           ,OTHLEN=300)
      CHARACTER AUTHOR(AUTLEN),KEYWDS(KEYLEN),
     +          OTHERS(OTHLEN),TITLE(TITLEN)
      CHARACTER ALABEL* (6),JOURNL* (4),MONTH* (9),
     +          LANG* (3),SHARE* (3)
```

```
 COMMON /CREFST/ALABEL,JOURNL,MONTH,LANG,SHARE,AUTHOR,
+       TITLE,KEYWDS,OTHERS
```

where

- JOURNL contains the journal in which the algorithm was published (possible values are cacm, toms or topl),
- VOLUME, NUMBER, MONTH and YEAR store the volume, number, month and year of publication of the main reference,
- PAGEST and PAGEND give the page range of the main reference,
- the author and title are stored in the arrays AUTHOR and TITLE,
- the algorithm number (in two instances this contains a letter), implementation language (F = Fortran, A60 = Algol 60, PLI = PL1, R = Ratfor, N = None), and the Share index are placed in ALABEL, LANG and SHARE respectively;
- KEYWDS is an array containing the list of keywords separated by semicolons,
- the array OTHERS stores associated Remarks and Certifications. Each remark is separated by a semicolon and contains, as a list separated by commas
  - type of remark (R = Remark, C = Certification),
  - journal of publication (cacm or toms)
  - page range – either a pair of number separated by -- or a single integer for a one page remark,
  - the volume, number, month and year of the publication,
  - the author.

Two example programs are included which use these routines to generate a BIBTEX database and a cumulative index sorted by the SHARE index.

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