Cumulative Index to the ACM Algorithms

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Abstract

This report contains a cumulative index to the *Collected Algorithms of the ACM*. The algorithms are classified using the modified SHARE classification, several different views of which are provided in Chapter 1. The source codes of these routines originally appeared in the *Communications of the ACM* and, from Algorithm 493, in the *ACM Transactions on Mathematical Software*. All algorithms up to and including those appearing in the December 1991 issue of TOMS are included in the index. Information on how to obtain sources of the algorithms is given in Appendix A.

The references given in the index provide the original source in bold face followed by any published remarks or certificates. The format of each reference is

<journal> <volume>:<page>

where <journal> is C for CACM, T for TOMS and, in the single case of Algorithm 568, X for *Transactions on Programming Languages and Systems*.

The index was built from a bibliographic database which is an extension to that previously provided as Algorithm 620. This extended database plus a set of Fortran 77 routines to manipulate individual items has been published as [1]. The complete submitted remark is included in this report as Appendix B.

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

We hope that users of numerical software will find this index a good starting point in their search for reliable public domain numerical routines.

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Chapter 1

The SHARE Classification

A1	Real Arithmetic, Number Theory
A2	Complex Arithmetic
B1	Trig and Inverse Trig Functions
B2	Hyperbolic Functions
B3	Exponential and Logarithmic Functions
B4	Roots and Powers
C1	Operations on Polynomials and Power Series
C2	Zeros of Polynomials
C5	Zeros of one or more Nonlinear Equations
C6	Summation of Series, Convergence Acceleration
D1	Quadrature
D2	Ordinary Differential Equations
D3	Partial Differential Equations
D4	Differentiation
D5	Integral Equations
E1	Interpolation
E2	Curve and Surface Fitting
E3	Smoothing
E4	Minimizing or Maximizing a Function
F1	Matrix Operations, including Inversion
F2	Eigenvalues and Eigenvectors of a Matrix
F3	Determinants
F4	Simultaneous Linear Equations
F5	Orthogonalization
G1	Simple Calculations on Statistical Data
G2	Correlation and Regression Analysis
G5	Random Number Generators
G6	Permutations and Combinations
G7	Subset Generators
H	Operations Research, Graph Structure
I5	Input – Composite
J6	Plotting
K2	Relocation
L2	Compiling
M1	Sorting
M2	Data Conversion and Scaling
O2	Simulation of Computing Structure
R2	Symbol Manipulation
S	Approximation of Special Functions
Y1	Physics Applications
Z	All Others

Figure 1.1: Classification by SHARE index

Z	All Others
S	Approximation of Special Functions
G6	Combinations and Permutations
L2	Compiling
A2	Complex Arithmetic
I5	Composite Input
O2	Computing Structure Simulation
C6	Convergence Acceleration
M2	Conversion and Scaling of Data
G2	Correlation and Regression Analysis
E2	Curve and Surface Fitting
M2	Data Conversion and Scaling
F3	Determinants
D2	Differential Equations, Ordinary
D3	Differential Equations, Partial
D4	Differentiation
F2	Eigenvalues and Eigenvectors of a Matrix
B3	Exponential and Logarithmic Functions
E4	Function Minimizing or Maximizing
H	Graph Structure, Operations Research
B2	Hyperbolic Functions
I5	Input—Composite
D5	Integral Equations
E1	Interpolation
F1	Inversion of a Matrix
F4	Linear Equations, Simultaneous
F1	Matrix Operations, including Inversion
B3	Logarithmic Functions and Exponential
F2	Matrix Eigenvalues and Eigenvectors
F1	Matrix Operations, Including Inversion
F3	Matrix, Determinant of
E4	Maximizing a Function
E4	Minimizing a Function
C5	Nonlinear Equations, Zeros of
A1	Number Theory

Figure 1.2: SHARE classification by subject

C1	Operations on Polynomials and Power Series
H	Operations Research, Graph Structure
D2	Ordinary Differential Equations
F5	Orthogonalization
D3	Partial Differential Equations
G6	Permutations and Combinations
Y1	Physics Applications
J6	Plotting
C1	Polynomials, Operations on
C2	Polynomials, Zeros of
C1	Power Series, Operations on
B4	Powers and Roots
D1	Quadrature
G5	Random Number Generators
A1	Real Arithmetic
G2	Regression and Correlation
K2	Relocation
B4	Roots and Powers
M2	Scaling and Conversion of Data
C6	Series, Summation and Convergence Acceleration of
G1	Simple Calculations on Statistical Data
O2	Simulation of Computing Structure
F4	Simultaneous Linear Equations
E3	Smoothing
M1	Sorting
S	Special Functions, Approximation of
G2	Statistical Data, Correlation and Regression Analysis of
G1	Statistical Data, Simple Calculations on
G7	Subset Generators
C6	Summation of Series
E2	Surface and Curve Fitting
R2	Symbol Manipulation
B1	Trig and Inverse Trig Functions
F5	Vectors, Orthogonalization of
C5	Zeros of one or more Nonlinear Equations
C2	Zeros of Polynomials

Figure 1.2: SHARE classification by subject (contd.)

S04 Bernoulli and Euler Numbers and Polynomials
S18 Bessel Function, Modified
S19 Bessel Functions of Complex Argument
S18 Bessel Functions of Pure Imaginary Argument
S17 Bessel Functions of Real Argument
S20 Bessel and Related Functions, Miscellaneous
S14 Beta Function and Incomplete Beta Function
S03 Binomial Coefficients
S07 Circular Functions, Miscellaneous
S19 Complex Argument, Bessel Functions of
S13 Cosine Integrals
S23 Curve-Fitting
S04 Derivatives and Differences of Zero
S15 Derivatives
S04 Differences and Derivatives of Zero
S23 Differentiation, Numerical
S21 Elliptic Integrals and Functions
S15 Error Integral
S04 Euler and Bernoulli Numbers and Polynomials
S13 Exponential Integrals
S14 Factorial Function
S03 Factorials
S22 Functions: Miscellaneous Higher Mathematical Functions
S14 Gamma Function and Incomplete Gamma Function
S15 Hermite Polynomials and Functions
S15 Higher Integrals
S22 Higher Mathematical Functions, Miscellaneous
S18 Imaginary Argument, Bessel Functions of
S14 Incomplete Beta and Gamma Functions
S13 Integrals of Exponentials, Logarithms, Sines, Cosines, etc.
S21 Integrals, Elliptic
S15 Integrals: Higher Integrals and the Error Integral

Figure 1.3: Classification of Special Functions

S23 Integration, Numerical
S23 Interpolation
S04 Inverse Powers, Sums of
S19 Kelvin Functions
S16 Legendre Functions
S13 Logarithmic Integrals
S22 Miscellaneous Higher Mathematical Functions
S18 Modified Bessel Functions
S15 Moments
S23 Numerical Differentiation and Integration
S03 Partitions
S14 Polygamma Function
S15 Polynomials, Hermite
S04 Powers and Inverse Powers, Sums of
S14 Psi Function
S13 Sine Integrals
S07 Spherical Functions, Miscellaneous
S04 Sums of Powers and of Inverse Powers
S21 Theta Functions
S07 Trigonometric Functions, Natural
S04 Zero, Differences and Derivatives of

Figure 1.3: Classification of Special Functions (contd.)

Chapter 2

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357	An Efficient Prime Number Generator	**C12:563** C16:489
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346	F-Test Probabilities	**C12:184**
349	Polygamma Functions with Arbitrary Precision	**C12:213** T1:380
395	Student's f-Distribution	**C13:617** T5:238 T7:247
396	Student's f-Quantiles	**C13:619** T5:238 T7:250
404	Complex Gamma Function	**C14:48** C16:489
421	Complex Gamma Function with Error Control	**C15:271**
435	Modified Incomplete Gamma Function	**C15:993** T4:296
442	Normal Deviate	**C16:51**
465	Student's t Frequency	**C16:690**
487	Exact Cumulative Distribution of the Kolmogorov-Smirnov Statistic for Small Samples	**C17:703** T2:111 T3:285
518	Incomplete Bessel Function I_0: The von Mises Distribution	**T3:279**
519	Three Algorithms for Computing Kolmogorov-Smirnov Probabilities with Arbitrary Boundaries and Certification of Algorithm 487	**T3:285**
542	Incomplete Gamma Functions	**T5:482**
571	Statistics for von Mises' and Fisher's Distribution of Directions: $I_1(x)/I_0(x)$ $I_{1.5}(x)/I_{.5}(x)$	**T7:233**
610	A Portable Fortran Subroutine for the Derivation of the Psi Function	**T9:494**
654	Fortran Subroutines for Computing the Incomplete Gamma Function Ratios and their Inverse	**T13:318**

S15

11	Evaluation of the Hermite Polynomial $H_n(X)$ by Recursion	**C3:353**
123	Real Error Function erf(x)	**C5:483** C6:316 C6:618 C7:145 C10:377
180	Error Function – Large x	**C6:314** C10:377
181	Complimentary Error Function – Large x	**C6:315** C7:702 C10:377
185	Normal Probability for Curve Fitting	**C6:386**
209	Gauss	**C6:616** C7:148 C7:482 C10:377
226	Normal Distribution Function	**C7:295** C10:377

272	Procedure for the Normal Distribution Functions	**C8:789** C10:377 C11:498
299	Chi-Squared Integral	**C10:243** C11:271 T2:393 T11:185
304	Normal Curve Integral	**C10:374** C10:377 C11:271 C12:565 C13:624
363	Complex Error Function	**C12:635** C15:465
462	Bivariate Normal Distribution	**C16:638**
521	Repeated Integrals of the Coerror Function	**T3:301**
680	Evaluation of the Complex Error Function	**T16:47**

S16

13	Evaluation of the Legendre Polynomial $P_n(X)$ by Recursion	**C3:353** C4:105 C4:181
47	Associated Legendre Functions of the First Kind for Real or Imaginary Arguments	**C4:178** C6:446 C12:635
62	A Set of Associate Legendre Polynomials of The Second Kind	**C4:320** C4:544
259	Legendre Functions for Arguments Larger than One	**C8:488** T3:204

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21	Bessel Function for a Set of Integer Orders	**C3:600** C8:219
22	Riccati-Bessel Functions of First and Second Kind	**C3:600** C13:448
44	Bessel Functions Computed Recursively	**C4:177**
49	Spherical Neumann Function	**C4:179** T4:295
124	Hankel Function	**C5:483** C8:790
163	Modified Hankel Function	**C6:161** C6:522
236	Bessel Functions of the First Kind	**C7:479** C8:105 T1:282
484	Evaluation of the Modified Bessel Functions $K_0(z)$ and $K_1(z)$ for Complex Arguments	**C17:524**
498	Airy Functions using Chebyshev Series Approximations	**T1:372** T7:404
597	Sequence of Modified Bessel Functions of the First Kind	**T9:242**

S18

5	Bessel Function I Series Expansion	**C3:240**
6	Bessel Function I Asymptotic Expansion	**C3:240**
214	q-Bessel Functions $I_n(t)$	**C6:662** C7:349
228	Q-Bessel Functions $\bar{I}_n(t)$	**C7:295**
511	CDC 6600 Subroutines IBESS and JBESS for Bessel Functions $I_\nu(x)$, $J_\nu(x)$, $\nu \geq O$ $x \geq O$	**T3:93** T4:411

S19

57	Ber or Bei Function	**C4:181** C5:392 C5:438
644	A Portable Package for Bessel Functions of a Complex Argument and Non-negative order	**T12:265** T16:404

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88	Evaluation of Asymptotic Expression for the Fresnel Sine and Cosine Integrals	**C5:280** C6:618
89	Evaluation of the Fresnel Sine Integral	**C5:280** C6:618
90	Evaluation of the Fresnel Cosine Integral	**C5:281** C6:618
213	Fresnel Integrals	**C6:617** C7:661
244	Fresnel Integrals	**C7:660**
301	Airy Function	**C10:291** C10:453
505	A List Insertion Sort for Keys with Arbitrary Key Distribution	**T2:204**

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55	Complete Elliptic Integral of The First Kind	**C4:180** C6:166
56	Complete Elliptic Integral of The Second Kind	**C4:180** C9:12
73	Incomplete Elliptic Integrals	**C4:543** C4:544 C5:514 C6:69 C6:167
149	Complete Elliptic Integral	**C5:605** C6:166 T4:95
165	Complete Elliptic Integrals	**C6:163** C12:38
549	Weierstrass' Elliptic Functions	**T6:112**
577	Algorithms for Incomplete Elliptic Integrals	**T7:398**

S22

10	Evaluation of the Chebyshev Polynomial $T_n(X)$ by Recursion	**C3:353** C4:181
12	Evaluation of the Laguerre Polynomial $L_n(X)$ by Recursion	**C3:353**
36	Tchebycheff	**C4:151**
110	Quantum Mechanical Integrals of Slater-Type Orbitals	**C5:389** C5:393
111	Molecular-Orbital Calculation of Molecular Interactions	**C5:390**
132	Quantum Mechanical Integrals Over all Slater-Type Integrals	**C5:551**
184	Erlang Probability for Curve Fitting	**C6:386**
191	Hypergeometric	**C6:388** C7:244 C17:589
192	Confluent Hypergeometric	**C6:388** C7:244
227	Chebyshev Polynomial Coefficients	**C7:295**
282	Derivatives of e^x/x, $\cos(x)/x$ and $\sin(x)/x$	**C9:272** C13:53
292	Regular Coulomb Wave Functions	**C9:793** C12:278 C12:280 C13:573
300	Coulomb Wave Functions	**C10:244** C12:279 C12:692 C16:308
327	Dilogarithm	**C11:270**
332	Jacobi Polynomials	**C11:436** C13:449 C18:116
352	Characteristic Values and Associated Solutions of Mathieu's Differential Equation	**C12:399** C13:750 C15:1074
388	Rademacher Function	**C13:510**
389	Binary Ordered Walsh Functions	**C13:511**

390	Sequency Ordered Walsh Functions	**C13:511**
490	The Dilogarithm Function of a Real Argument	**C18:200** T2:112
537	Characteristic Values of Mathieu's Differential Equations	**T5:112**

S23

234	Poisson-Charlier Polynomials	**C7:420** C8:105

Z : All Others

45	INTEREST	**C4:178** C6:520
112	Position of Point Relative to Polygon	**C5:434** C5:606
117	Magic Square (Even Order)	**C5:435** C5:440 C6:39 C6:105
118	Magic Square (Odd Order)	**C5:436** C5:440 C5:606 C6:39 C6:105
136	Enlargement of a Group	**C5:555**
148	Term of Magic Square	**C5:605** C6:168 C6:168
199	Conversions Between Calendar Date and Julian Day Number	**C6:444** C7:661
240	Coordinates On An Ellipsoid	**C7:546**
246	Graycode	**C7:701** C8:382 T1:285 T11:441
252	Vector Coupling or Clebsch-Gordan Coefficients	**C8:217**
260	6-J Symbols	**C8:492**
261	9-J Symbols	**C8:492**
355	An Algorithm for Generating Ising Configuration	**C12:562**
364	Coloring Polygonal Regions	**C12:685**
391	Unitary Symmetric Polynomials	**C13:512** C15:49
398	Tableless Date Conversion	**C13:621** C15:918
428	Hu-Tucker Minimum Redundancy Alphabetic Coding Method	**C15:360** C16:490
444	An Algorithm for Extracting Phrases in a Space-Optimal Fashion	**C16:183**
445	Binary Pattern Reconstruction from Projections	**C16:185** C16:186
455	Analysis of Skew Representations of the Symmetric Group	**C16:571**
479	A Minimal Spanning Tree Clustering Method	**C17:321** C18:119 T2:110
499	An Efficient Scanning Technique	**T2:82**
523	CONVEX: A New Convex Hull Algorithm for Planar Sets	**T3:411**
528	Framework for a Portable Library	**T4:177** T5:524
532	Software for Roundoff Analysis	**T4:388**
536	An Efficient One-Way Enciphering Algorithm	**T5:108**
550	Solid Polyhedron Measures	**T6:121**
561	Fortran Implementation of Heap Programs for Efficient Table Maintenance	**T6:444**
564	A Test Problem Generator for Discrete Linear L_1 Approximation Problems	**T6:615**

568	PDS – A Portable Directory System	**X3:162**
588	Fast Hankel Transforms Using Related and Lagged Convolutions	**T8:369**
594	Software for Relative Error Analysis	**T9:125**
605	PBASIC – A Verifier Program for ANSI Minimal Basic	**T9:391**
606	NITPACK – An Interactive Tree Package	**T9:418**
607	Text Exchange System: A Transportable System for Management and Exchange of Programs and Other Text	**T9:427**
620	References and Keywords for *Collected Algorithms from ACM*	**T10:359** T11:305 T16:401
622	A Simple Macroprocessor	**T10:410**

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 [2],
3. a cumulative index based on the GAMS classification like the one in [3].

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 [2] and [3] 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 toms
```

where number is the number of the algorithm you require, e.g., to obtain algorithm 495 the message would be

```
send 495 from toms
```

to netlib@unix.hensa.ac.uk (UK/Europe) or netlib@research.att.com (US).

Using anonymous ftp connect to unix.hensa.ac.uk (129.12.21.7) from the UK and Europe or research.att.com (192.20.255.2) from the US, log in as anonymous and use your e-mail address as a password. To access the TOMS algorithms

```
cd netlib/toms
```

The algorithms currently available are

380, 386, 400, 403, 404, 406 – 408, 410, 413, 414, 419,
420, 432, 433, 458, 473 – 476, 478, 479, 483 – 485, 487,
488, 490, 493 –

Appendix B

A Remark on ACM TOMS Algorithm 620

We report on an enhanced version of the database originally reported in [6]. 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[4]. Following the practice used with BIBTEX[5], 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 [6]. 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.

Bibliography

[1] HOPKINS, T., AND MORSE, D. Remark on algorithm 620. *ACM Trans. Math. Softw. 16*, 4 (December 1990), 401–403.

[2] HOPKINS, T., AND MORSE, D. Cumulative index to the ACM algorithms. Tech. Rep. 64 (Revised), Computing Laboratory, University of Kent, Canterbury, UK, Oct. 1992.

[3] HOPKINS, T., AND MORSE, D. Cumulative index to the Applied Statistics algorithms. Tech. Rep. 71 (Revised), Computing Laboratory, University of Kent, Canterbury, UK, Oct. 1992.

[4] KNUTH, D. E. *The TEXbook*. Addison-Wesley, Reading, Massachusetts, 1984.

[5] LAMPORT, L. LATEX *User's Guide & Reference Manual*. Addison-Wesley, Reading, Massachusetts, 1986.

[6] RICE, J. R., AND HANSON, R. J. References and keywords for Collected Algorithms from ACM. *ACM Trans. Math. Softw. 10*, 4 (December 1984), 359–360.