A page number in *italics* indicates a figure.

absolute minimums, 514, 515 abstract method creation, 119 acceptance functions. See distribution functions accumulate method, 214-218, 225, 241 ADAPTER for probability distribution function, 376 additive sequence random number generation, 359-360, 365-369 al-Kashi, Jamshid Masud, 10 alternating series, 178 Array class, vectors as subclass of, arrays. See also matrices; vectors Java, 669 for linear equations, 246 associative law, rounding errors, 6 averages, 313 beta distribution, 672 Cauchy distribution, 681 comparing. See t-test error on, 313 exponential distribution, 688 Fisher-Snedecor distribution, 414 Fisher-Tippet distribution, 695 gamma distribution, 393 Laplace distribution, 703 log normal distribution, 710 normal distribution, 385 probability distributions, 369 Student distribution, 426 triangular distribution, 717 uniform distribution, 723

vector, 606-609, 611 Weibull distribution, 729 backward substitution algorithm, 243-245, 259-260 Bessel's correction factor, 313 beta distribution, 198, 671-680, Java implementation, 675-680 properties, table of, 672 Smalltalk implementation, 671-675 uniform distribution, relation to, 671 beta function, incomplete. See incomplete beta function binomial coefficients, 322 bisection method for finding zeroes, 134-140 continuity requirement, 134 general implementation, 136 iterations required, 135 Java implementation, 138-140 Smalltalk implementation, 136-138 speed of, 150 bit-pattern generators, 360 bracketing optimums for onevariable functions, 546-550 Breit-Wigner curve. See Cauchy distribution Brent's method, 150 Bulirsch-Stoer algorithm, 93, 98-101, 111, 746

calibrating sets, 607, 618

Cauchy distribution, 680-687, 682 Java implementation, 683-687 Smalltalk implementation, 681-683 CD ROM, accompanying, 741-746 centiles, 56, 133-134, 370 central moments, 313-314, 320-321. See also kurtosis; skewness; statistical moments; variance accurate accumulation derivation, 737-739 for probability density functions, robust implementation, 322-331 change of coordinates, covariance matrices, 616-618 chi-square, 188, 349 distribution, 436-448, 438 incomplete gamma distribution for, 438 Java implementation, 440-442 properties, table of, 437 Smalltalk implementation, 439-440 fit, 459 histograms, test on, 448-456 Java implementation, 453 Smalltalk implementation, 452-453 Poison distribution, test of, 448-449 random numbers generation, testing, 450, 453

1.	6 11 11 27	(0.6, 600, 614
chi-square (cont.)	constants, Smalltalk, 27	vector averages, 606–609, 611
scaled probability density	constrained cubic splines, 103–104	C programming language, 24
function, 449–452	continued fractions, 184–188	CRL algorithm, 274–288
Java implementation,	incomplete beta function, 198,	equations for, 275
454–456	198–205	general implementation,
Smalltalk implementation,	incomplete gamma function,	275–277
450–452	190, 197–198	generalizing, 277
test, 436–448	Java implementation, 186–188	Java implementation, 279–287
confidence level equations,	Lentz's method, 185	rounding problems, 287–288
438–439	linear notation for, 185	Smalltalk implementation,
on histograms, 448–456	Smalltalk implementation,	277–279
weighted points	185–186	speed, 276
equation for, 437	convergence	CRL inversion algorithm, 231
general implementation,	continued fractions, 185	cubic spline interpolation, 74, 78,
442–443	infinite series, 178, 181	102–109
Java implementation,	correlation. See covariance	choosing as a method, 110-111
446–448	matrices, correlation	definition of cubic spline, 102
Smalltalk implementation,	correlation coefficients between	general implementation,
444–445	errors, 460	103–104
class diagrams, 26-27	covariance clusters, 643-645	Java implementation, 107–109
classes, 3-4, 653-656, 662-667	covariance matrices, 605-616	Smalltalk implementation,
class hierarchies, 3-4	accumulation code examples,	104–106
cluster analysis, 625-642	608, 611	
assigning data to clusters, 626	accurate accumulation	data analysis. See data mining
centers, initial sets of, 625	derivation, 739–740	data encapsulation, 3
covariance clusters, 643-645	calibrating sets, 607	data mining, 1, 598-645
distance functions, 626, 628	change of coordinates, 616-618	class diagrams, 598, 600
Euclidean cluster	cluster analysis with, 643-645	cluster analysis. See cluster
implementation, 633-634,	components, 606–607	analysis
640–642	correlation, 605-607	covariance. See covariance
Euclidean distance, 626, 640	correlation coefficient defined,	matrices
general implementation,	606	data reduction using covariance
627–629	data reduction from, 617	matrices, 617
Java implementation, 634-642	eigenvalues, 617	data server object, 601-605, 628
K-cluster algorithm, 625	error matrix, relation to, 606	distances. See Mahalanobis
number of clusters, 626–627	estimated correlation coefficient,	distance
Smalltalk implementation,	606–607	goal of, 601
629–634	estimated covariance, 606	Mahalanobis distance, 617–625
code reuse, 2–3	evaluation of measurements,	multidimensional probability
collect: iteration method,	607	distribution, 616–617
148–149	general implementation,	preparation of data, 599
compute methods for numeric	607–608	shopping cart analysis, 607
parameters, 12–14, 17–19	inverse, 618	data reduction using covariance
computer numerical precision	Java implementation, 611–616	matrices, 617
Java implementation, 16–22	Mahalanobis distance, 618	defaultNumericalPrecision
parameters of, 10–12	multidimensional probability	algorithm for, 14, 19
Smalltalk implementation,	distribution, 616–617	defined, 11–12
12–16	shopping cart analysis, 607	deflation, 148
congruential random number	Smalltalk implementation,	density functions. See probability
generation, 358–359,	608–610	density functions
363–366	uses of, 607	derivative evaluation, 37–38
	•	*

derivative method, 41, 43, 50 derivatives derivative method, 41, 43, 50 at optima, 514–515 of polynomials, 40–41, 43, 50 searching for the extremes, 133 desired precision, 10 desiredPrecision, 117 determinants, 260, 272–274 DhbFloatingPointMachine class, 12 DhbMath class, 16 DhbNumericalMethods, 743 diagonal rational functions, 74, 77, 99 diffracted light, computation of, 153–154 distance functions, 626, 628 distribution demo, 745 distribution function of a gamma probability density function, 189 distributions. See probability distributions division, integer, in Smalltalk, 25 double dispatching, 41, 213, 217, 658–660 eigenvalues and eigenvectors, 288–309 covariance matrix, 617 defined, 288 finding. See Jacobi's algorithm finding largest absolute value, 288–289 general implementation, 289–290 Java implementation, 292–296 Smalltalk implementation,	error matrices, 460–461, 475, 477–478, 483, 606 errors on average, 313 estimated covariance, 606 estimated error, 460, 477, 481 estimated polynomials, 462, 474 estimated variance, 460, 483 estimation, 456–459 Euclidean distance, 626 Euler-Maclaurin formula, 155 Euler's integral, 62 excess. See kurtosis execution speed, 23–24 expectation values, 737–739 experimental conditions, 456–458 exponential distribution, 687–694, 688 Java implementation, 691–694 properties, table of, 688 Smalltalk implementation, 689–690 exponential function, 178 extended Newton algorithms, 515–516 extrapolation, 73 factorial, 62, 67 factors, rounding errors, 6–7 file reader utility, 745–746 finding zeroes of functions. See zeroes of functions, finding Fisher-Snedecor distribution, 413–424, 415 equations for, 413 incomplete beta function for, 198 Java implementation, 419–424 properties, table of, 414 Smalltalk implementation, 416–418 Fisher-Tippet distribution,	demonstration class, 359–360 DhbFloatingPointMachine class, 12 mantissas, 648 rounding problems, 6–9, 647–649 forward substitution algorithm, 259–260, 262–263, 268 fractions, 25 fractions, continued. See continued fractions F-test, 413–424 beta distribution for, 198 code example in Java, 419 code example in Smalltalk, 414 histograms, use with, 351, 358 Smalltalk implementation, 418–419 use in robust central moments implementation, 330 functions, 33–70 beta, 69–70 error, 56–62 expectation values of, 320–321 exponential, 178 gamma, 62–69 goal, 511 integration of. See integration interpolation. See interpolation inverse, 73, 133 Java implementation, 36–38 likelihood, 457 mathematical, defined, 35 multivariable, 35–36 one-variable, 35–36 optimization. See optimization problems parametrized interface, 490 poles in, 98 polynomials. See polynomials probability density. See
finding largest absolute value, 288–289 general implementation, 289–290	incomplete beta function for, 198 Java implementation, 419–424 properties, table of, 414	one-variable, 35–36 optimization. <i>See</i> optimization problems parametrized interface, 490
292–296 Smalltalk implementation, 290–292 Jacobi's algorithm. See Jacobi's algorithm number per matrix, 288	416–418 Fisher-Tippet distribution, 694–702, 695 Java implementation, 698–702 properties, table of, 695 Smalltalk implementation,	polynomials. See polynomials probability density. See probability density functions rational, defined, 98 searching for the extremes, 133 Smalltalk implementation,
orthogonality of, 288 orthogonal matrices, 296–298 symmetrical matrices, 296–309 equality of floating point numbers, 22–23 error function, 56–62, 384, 387	696–698 floating point representation, 4–5 additive sequence random number generation, 359–360 comparing numbers, 22–23 computing parameters of, 12	35–36 tabulated, 110 zeroes of. <i>See</i> zeroes of functions, finding

gamma distribution, 392-403	goal functions, 511	histograms, 331-358
incomplete gamma function,	golden section search, 540-546	bins, 331–333
188–189	gradients, 377, 489, 502, 514	chi-square test on, 448-456
Java implementation, 397-403	greedy algorithms, 515	Java implementation, 453
maximum, finding, 540, 543		Smalltalk implementation,
properties, table of, 393	Hessian matrices, 516	452–453
Smalltalk implementation,	hiding the implementation, 3	contents, 331
392–397	hierarchies, 2	error on bin contents, 332
gamma function, 62-69	hill-climbing algorithms, 516-539	general implementation, 333
Euler's integral, 62	abstract class for	instance variables, 334, 343-344
incomplete. See incomplete	Java implementation,	Java implementation, 333-343
gamma function	534–536	Kurtosis of, 354. See also
Java implementation, 66-69	Smalltalk implementation,	kurtosis
Smalltalk implementation,	520–522	least-square fits of, 458,
64–66	bracketing one-variable	483–484
Gaussian distribution, generalized	functions, 546–550	likelihood function, 499
error function, 57–58	classes, common	limits, setting, 333
Gaussian elimination, 244–245,	Java implementation,	maximum-likelihood fits of
274	524–539	probability density functions,
generalized error function, 57	Smalltalk implementation,	458, 499–509
genetic algorithm, 568-592	518–520	overflow, 332, 335
abstract Java implementation,	direction finding. See Powell's	parameters of, 331
582–584	algorithm	Poisson distributions, 332
chromosome manager object,	general algorithm, 516	probability distributions from,
571–572	general implementation,	403–408
Java implementation,	517–518	scaled probability density
578–582	genetic algorithm. See genetic	function, 449–452
Smalltalk implementation,	algorithm	Java implementation,
573–575	limitations, 593	454–456
chromosome representation,	maximums of vector functions,	Smalltalk implementation,
569	552, 554	450–452
crossover, 568-569	multiple strategy approach,	Smalltalk implementation,
diagram of, 570	592–596	333–343
general implementation,	one-variable functions, 540-546	statistical moments from, 333
569–572	optimizing point classes,	underflow, 332, 335
genetic optimizer object, 571,	524–527	Holland, John, 568
576–578	point factory classes, 531-534	hook methods, 116
Java implementation, 578-592	Powell's algorithm. See Powell's	Horner's rule, 40, 88
mature population, 571	algorithm	, ,
mutations, 568	projected function classes	identity matrices, 212
reproduction, 571	Java implementation,	incomplete beta function, 198,
selection process, 572	536–539	198–205
Smalltalk implementation,	Smalltalk implementation,	equations for, 199
573–578	522–524	Java implementation, 202–205
termination criteria, 572	simplex algorithm, 558-567	Smalltalk implementation,
vector chromosomes, 573,	transforming vector functions	199–202
585–589	to one-variable functions,	incomplete gamma function,
vector function, maximum of,	521–522, 530–539	188–198
576, 585	valley problem, 551, 559	for chi-square distribution, 438
vector implementation, Java,	vector classes, 527–531	equations for, 189–190
589–592	•	,

	4	
gamma distribution from, 392, 397	trapeze method. See trapeze	methods for successive
	integration method	approximations, 118 nonlinear function successive
Java implementation, 193–198	interfaces, 36, 667	
overflow, avoiding, 190	interpolation, 73–111	approximation, 484
Smalltalk implementation, 190–193	choosing a method of, 110–111 class diagram, 75	for optimization problems, 517–518
term servers, 192–193, 195–197	cubic spline, 74, 78, 102–111	relative precision, 126–130
incrementing, 28	diagonal rational functions, 74,	setup phase, 113–115
indices, 43, 48	77	Smalltalk implementation,
infinite series, 177–184	error estimates with, 110	117–121, 126–128
alternating series, 178	file reader utility, 745–746	steps in, general, 113–114
class diagrams, 179–180	Lagrange polynomial. See	successive approximations, 115,
continued fractions, 184–188	Lagrange interpolation	116, 118, 484
convergence, 178, 181	polynomial	table of, 131
exponential function, 178	Neville, 92–98, 110–111, 166	trapeze integration method,
incomplete beta function,	Newton, 88–92, 110–111	157–158
198–205	periodic functions, 74	IterativeProcess class, 117
incomplete gamma function,	polynomial, 74, 473	,,
189, 195–197	range of intended use, 74–76	Jacobi's algorithm, 296-309
Java implementation, 183–184	sample points, 73	angle of rotation, 298, 300
rounding errors, 178, 181	smoothness of functions, 110	annihilation of off-diagonal
Smalltalk implementation,	interval acceptance functions, 370,	elements, 297
181–182	376	general implementation, 300
term servers, 181–182	inverse functions, 73, 133,	Java implementation, 305-309
trigonometric functions, 178	158–164	orthogonal matrices, 296-298
inheritance, 3–4	inverses of matrices, 243	Smalltalk implementation,
in class diagrams, 26	calculating, 274–288	300–305
Java, 664–666	general implementation,	steps in, 299
instance variables in class diagrams,	275–277	James, Fred, 511
26	Java implementation, 279–287	Java
integral method, 41, 43, 52	permutation matrices, 259	abstract classes, 666–667
integration, 153–174	pseudo-inverses, 277, 287	arrays, 669
classes, diagram of, 154	rounding problems, 287–288	CD ROM, code from, 744–746
diffracted light, computation of,	Smalltalk implementation,	classes, 662–667
153–154	277–279	classes related to functions, 35
Euler's integral, 62	time required, 276, 276	code conventions, 27–28
integral method, 41, 43, 52	I(p), 457–458	collection classes, 669
inverse function, 158–164	iterations, 117	constructor method, 662
iterations, number required,	iterative algorithms, 113–131	distribution demo, 745
171–172	bisection method for finding	Double.NaN, 67
methods compared, 171–174	zeroes, 135–136	exception handling, 668
open integrals, 170–171 of polynomials, 40–41	class diagram of, 114 cleanup phase, 113–114	execution speed, 24 factory classes, 531
precision obtained, 171–172	controlling number of iterations,	file orientation, 661
Romberg integration algorithm,	122	file reader utility, 745–746
165–171	criteria for stopping, 115	function implementation, 36–38
series expansions of integrals,	hook methods, 116	HashTable class, 669
155	iterative phase, 113–114	incrementing, 28
Simpson integration algorithm,	Java implementation, 121–126,	indices, 48
162–166, 171	128–130	inheritance, 664–666
singularities, 157, 170		inner classes, 37

general implementation, 462	components, 209	general implementation,
Java implementation, 466-471	covariance, 605-616	501-502
Smalltalk implementation,	CRL inversion algorithm, 231	gradient calculation, 502
462–466	defined, 209	I(p), 500
local minimums, 514	determinants of, 260, 272-274	Java implementation, 505-509
logarithms with gamma function,	dot products of, 210	likelihood function, 499
63–64, 67	eigenvalues and eigenvectors. See	methods for, 492
log normal distribution, 710–716,	eigenvalues and eigenvectors	probability density functions,
711	error, 460–461, 475–478, 483	499–509
lower matrices, 257	Hessian, 516	Smalltalk implementation,
LUP decomposition, 257–272	identity, 212	502-503
defined, 257	instance variables for, 216	starting value computation, 372,
determinants from, 272–274	invariant transformations of,	381
general implementation of,	244–245	means. See averages
259–260	inverting, 243, 274–288	methods
Java implementation of,	Java implementation of,	abstract, 119
264–272	231–242	hook, 116
LU decompositions, 258	in linear algebra, 243	Java, 662–667
matrix inversion with, 274	lower, 257	Smalltalk, 27, 119, 653-656
permutation matrices, 257–259	LUP decompositions, 216, 219	metrics, Mahalanobis distance, 618
for polynomial least-square fit,	multiplication, 210-212, 216,	minimums, 514–515
478–479	275	MINUIT, 511
proof of existence, 258–259	operations on, 211	Mitchel-Moore random number
rounding problems, 287–288	orthogonal, 296-298	generator, 359–360, 367–369
Shur's complement, 258–259	permutation, 257–260, 273	moments. See statistical moments
Smalltalk implementation of,	pivoting, 244–245, 248–249,	Moore-Penrose inverses, 277, 287
260–264	254–255	multidimensional probability
	products with vectors, 211, 216	distribution, 616–617
machine precision	pseudo-inverses, 277, 287	multiple dispatching
algorithm for, 13, 18	rounding problems, 287–288	Smalltalk, 659–660
defined, 11	row exchange and replacement,	vector multiplication with, 217
Mahalanobis center, 620–621	244–245	
Mahalanobis distance, 617–625	Shur's complement, 258–259,	name spaces, 27–28
with covariance clusters,	275	natural cubic splines, 103–104
643–645	Smalltalk implementation of,	natural logarithm, calculating,
defined, 618	216–222	158–164
examples, 618–619	square, 209, 212, 243	negative machine precision, 11,
general implementation,	square method, 216	13–14, 18
619–620	Strassen's algorithm, 275	Neville interpolation, 92–98,
Java implementation, 622–625	symmetrical, 212, 296–309	110–111, 165–166
Mahalanobis center, 620–621	SymmetricMatrix class, 231	new method, 27, 656, 662
Smalltalk implementation,	transposes, 211–212, 216, 221,	Newton interpolation, 88–92
620-622	241	compared to other methods,
sorting by, 620–621, 623–624	triangular, 243–245	110–111
mantissas, 5, 648	upper, 257	for cubic spline interpolation,
Markov's inequality, 370	maximumIterations, 117	103–104
mathematical objects, 2	maximum-likelihood estimation,	Newton-Ralphson algorithm. See
matrices	457, 499	Newton's method for finding
accumulate method, 217–218,	maximum-likelihood fit	zeroes
241 CLP algorithm 274 278	function to minimize, 501	

CLR algorithm, 274–278

Newton's method for finding	common classes	pivoting matrices, 244-245,
zeroes, 140–147	Java implementation,	248–249, 254–255
extended, 515-516	524–539	points method, 81
inverse distribution functions,	Smalltalk implementation,	Poisson distribution, 332, 448-449
370, 372	518-520	poles, Bulirsch-Stoer interpolation,
Java implementation, 144-147	extended Newton algorithms,	98
roots of polynomials, 148	515–516	polymorphism, 2, 4
Smalltalk implementation,	general implementation,	polynomial fits. See least-square fit,
142–144	517–518	polynomials
speed of, 150	genetic algorithm. See genetic	polynomials, 39–56
nonlinear equations, successive	algorithm	as bit-pattern generators, 360
approximations solution of,	golden sections, 540	coefficients, 39
500	gradients, 514	cubic splines, 102
nonlinear functions, least-square	greedy algorithms, 515	defined, 39
fit. See least-square fit, with	Hessian matrices, 516	deflate method, 50
nonlinear dependence	hill climbing. See hill-climbing	deflation, 148
normal distribution, 384–392	algorithms	derivatives of, 40–41
integral of. See error function	integer goal functions, 569	division algorithm, 45, 51
Java implementation, 387–392	limitations of algorithms, 593	eigenvalues as roots, 288
in least-square estimation,	local-optimums problem, 568	estimated, 474
457–458	minimums, 514–515	evaluation of, 39–40
properties, table of, 384	multiple strategy approach,	Horner's rule, 40
required for F-test, 413	592–596	implementation, general, 41
Smalltalk implementation,	one-variable functions, 540–546	integrals of, 40–41
384–387	optima, 514–515	interpolation. See interpolation
vector components with, 616	optimizing point classes,	iterative algorithms with,
numbers	524–527	127–130
floating point. See floating point	point factory classes, 531–534	Java implementation, 48–55
representation	Powell's algorithm. See Powell's	Lagrange. See Lagrange
representation of, 4–5	algorithm	interpolation polynomial
1: 1	projected function classes	least square fit. See least-square
object oriented programming	Java implementation,	fit, polynomials
(OOP), 2–4	536–539	multiplication algorithm, 47,
OneVariableFunction interface,	Smalltalk implementation,	52–53
36–37	522–524	operations on, 41
one-variable functions	random-based algorithms, 515	roots, finding, 147–150
bracketing, 546–550	saddle points, 514	roots method, 53–54
optimization, 540–546	search spaces, 514	Smalltalk implementation, 42–47
OOP (object oriented	simplex algorithm, 558–567	
programming), 2–4 open integrals, 170–171	transforming vector functions to one-variable functions,	symbolic manipulation of, 42 pool dictionaries, 27
optimization problems, 510–515	521–522, 536–539	Powell's algorithm, 550–557
abstract class for	vector classes, 527–531	drawbacks, 551
Java implementation,	vector classes, 327–331	general implementation,
534–536	packages, 28, 663-664	551–552
Smalltalk implementation,	paramatrized function interface,	Java implementation, 554–557
520–522	490	modification in implementation,
algorithms for, table of, 515	Pearson type III distribution, 392	552
bracketing one-variable	permutation matrices, 257–260,	Smalltalk implementation,
functions, 546–550	273	552–554
class diagrams, 510, 512–513	pi, perimeter algorithm for, 10	steps in, 550–551
5.000 Giagraino, 510, 512 515	p., perimeter algorithm for, to	510po m, 550 551

precision computer numerical. See computer numerical precision desired, 10, 117 iterative processes, 117–119, 122 of numeric representations, 5, 9–10	experimental, 403–408, 456–458 exponential, 687–694, 688 Fisher-Snedecor, 413–424 Fisher-Tippet, 694–702, 695 gamma, 392–403 general implementation, 371 histograms, from, 403–408	bit-pattern generators, 360 chi-square confidence levels for, 450, 453 correlations in series, 359–360 Java implementation, 366–369 linear congruential, 358–359, 363–364, 366 Mitchel-Moore generator,
parameters, list of, 11	interval acceptance functions,	359–360, 367–369
relative precision, 126–130	370, 376	multiple series, separately
principal component analysis, 617 probability density functions,	inverse distribution functions, 370–372, 376, 383	reproducible, 361 seeds, 358, 361–362
369–370	Java implementation, 376–384	Smalltalk implementation,
beta distribution, 672	kurtosis of, 369. See also	361–366
Cauchy distribution, 681	kurtosis oi, 307. See aiso	tests for randomness, 359
chi-square tests of, 449	Laplace distribution, 702–709,	time as seeds, 362
distribution demo, 745	703	rational functions
experimental, 403	log normal distribution,	defined, 98
exponential distribution, 688	710–716, 711	diagonal, 74, 77, 99
Fisher-Snedecor distribution,	Markov's inequality, 370–371	real numbers, representation of,
414	multidimensional, 616–617	4–5
Fisher-Tippet distribution, 695	normal, 384–392	recurrence formula
from histograms, 403	normal distribution, 385	Bulirsch-Stoer algorithm, 99
I(p), 500	Pearson type III, 392	gamma function, 62–63
Laplace distribution's, 703	probability density functions,	Neville interpolation, 92–93
likelihood function, 499	369	reference systems, 209
log normal distribution's, 710	public methods for, 372	reflection formula, 63
maximum-likelihood fits,	skewness, 369. See also skewness	regula falsi, 150
499–509	Smalltalk implementations,	relative precision, 126-130
normal, 385	371–376	relativePrecision, 125-126
public methods for, 372	statistical moments, 311	reliability behavior, 728
scaled, 449–452	Student. See Student distribution	repartition functions. See
Student distribution, 426	t. See Student distribution	distribution functions
triangular distribution's, 717	triangular distribution, 716–722	resonance curve. See Cauchy
uniform distribution, 723	uniform distribution, 723-728	distribution
vector components with normal	unknown distribution function	Richardson's deferred approach to
distribution, 616, 618	implementation, 375,	the limit, 166
Weibull distribution, 729	382–383	road map of book, 29
probability distributions	variances of, 369, 371. See also	robust, defined, 457
ADAPTERs for, 376, 383	variances	robust methods for statistical
averages of, 369. See also	pseudo-inverses of matrices, 277,	moments, 320–330
averages beta, beta distribution	287	Romberg integration algorithm, 165–171, 370
Cauchy. See Cauchy distribution	radix, 5	roots, finding, 147–150
central moments, 369	algorithm for, 14, 18	rounding errors, 6-9
chi-square. See chi-square,	defined, 11	floating point representation,
distribution	random-based algorithms, 515	647–649
density functions. See	random number generation,	infinite series, 178, 181
probability density functions	358–369	matrix inversion, 287-288
distribution demo, 745	additive sequence, 359–360,	statistical moments, 320-321
distribution functions, 370–371	365–369	

saddle points, 514	classes, 653	central moments, 313-314, 320
sample points, 73, 80–81, 83	classes related to functions, 34	expectation values, 320-321
scaled probability density function,	class methods, 655-656	general implementation, 314,
449–452	code conventions, 27	322
searching for the extremes, 133	code objects, 656	from histogram contents, 333
search spaces, 514	collect: method, 657	Java implementation, 317-320,
shopping cart analysis, 607	DhbNumericalMethods, 743	326–331
Shur's complement, 258-259, 275	Dictionary class, 669	kurtosis, 314. See also kurtosis
simplex algorithm, 558-567	do: method, 657, 669	moment defined, 313
general implementation, 560	double dispatching, 658-660	for probability density functions,
initial point selection, 559	ENVY, 741–744	369
Java implementation, 563–567	execution speed, 24	robust implementation, 320–330
simplexes, 558–559	expressions, 651–652	rounding errors, 320–321
Smalltalk implementation,	factory classes, 531	skewness, 314. See also skewness
560–562	files of sample code, 742–743	Smalltalk implementation,
steps in, 558	function implementation, 35–36	314–316, 322–326
Simpson integration algorithm,	indices, 43	variance, 313. See also variance
162–166	inject:into: method,	statistics
skewness, 314, 316, 318–319, 324,	657–658	acceptance thresholds, 370
328	instance methods, 653–656	averages. See averages
beta distribution, 672	instance variables, 653	central moments, 313–314,
exponential distribution, 688	integer division, 25	320-321. See also statistical
Fisher-Snedecor distribution,	iterator methods, 657-658	moments
414	messages, 651–652	chi-square. See chi-square
Fisher-Tippet distribution, 695	methods, 27, 653–656	class diagram, 312
gamma distribution, 393	multiple dispatching, 659–660	classes related to, 410
Laplace distribution's, 703	new, 27, 656	estimation, 456–459
log normal distribution's, 710	objects, 651, 656	experimental distribution. See
normal distribution, 385	operators, 653	experimental distribution
for probability density functions,	OrderedCollection class, 669	Fisher-Snedecor distribution. See
369	precedence, 652	Fisher-Snedecor distribution
probability distributions, 369,	primer for Java programmers,	F-test. See F-test
371	651–660	gamma distribution. See gamma
Student distribution, 426	print0n method, 42–43	distribution
triangular distribution's, 717	semicolons (;), 655	histograms. See histograms
uniform distribution, 723	subapplications, list of, 743–744	kurtosis, 314. See also kurtosis
smallest number	syntax, 651–653	least-square fit. See least-square
computing, 11	triple dispatching, 659–660	fit
smallestNumber	types, 651, 658–660	linear regression, 460–471. See
algorithm for, 14, 19 defined, 11	speed of execution, 23–24 splines, 102	linear regression maximum likelihood fit. <i>See</i>
smallNumber, 11-12	square matrices, 209, 212, 243	maximum likelihood fit
Smalltalk, 651–660	standard deviation, 313	moments, 313. See also
abstract method creation, 119	comparing between data sets.	statistical moments
assignment operator, 653	See F-test	normal distribution. See normal
block closures, 35–36	Poisson distributions, 332	distribution
block context, 656	statistical analysis, 411, 412. See	observed results, comparing to
brackets, 656	also statistics	theory. See chi-square
CD ROM, code from, 741–744	statistical moments, 311–314	Poisson distibutions, 332
chunk format, 741	averages. See averages	probability distributions. See
class constructor methods, 656	Bessel's correction factor, 313	probability distributions
11000 0011011 00001 11101110009 000	Desired Controlled Include 515	producting distributions

random numbers. See random
number generators
skewness, 314. See also skewness
standard deviation, 313
Student distribution. See Student
distribution
t-test. See t-test
variance, 313. See also variances
Strassen's algorithm, 275
Student distribution, 198, 424–436
Java implementation, 431–436
properties, table of, 426
Smalltalk implementation,
426–430
successive approximation
algorithm, 115, 116
least-square fit with nonlinear
dependence, 482
methods for, 118
superclasses, 4
symmetrical matrices, 212, 296–309
270-307
tabulated functions, 110
tabulated functions, 110 t distribution. See Student
t distribution. See Student distribution
t distribution. See Student
t distribution. <i>See</i> Student distribution tensor products, 211, 214, 216,
t distribution. See Student distribution tensor products, 211, 214, 216, 224, 230 transposes of matrices, 211–212, 216, 221
t distribution. See Student distribution tensor products, 211, 214, 216, 224, 230 transposes of matrices, 211–212, 216, 221 trapeze integration method,
t distribution. See Student distribution tensor products, 211, 214, 216, 224, 230 transposes of matrices, 211–212, 216, 221 trapeze integration method, 155–164
t distribution. See Student distribution tensor products, 211, 214, 216, 224, 230 transposes of matrices, 211–212, 216, 221 trapeze integration method, 155–164 case of Romberg integration
t distribution. See Student distribution tensor products, 211, 214, 216, 224, 230 transposes of matrices, 211–212, 216, 221 trapeze integration method, 155–164 case of Romberg integration algorithm, 166
t distribution. See Student distribution tensor products, 211, 214, 216, 224, 230 transposes of matrices, 211–212, 216, 221 trapeze integration method, 155–164 case of Romberg integration algorithm, 166 compared to other methods, 171
t distribution. See Student distribution tensor products, 211, 214, 216, 224, 230 transposes of matrices, 211–212, 216, 221 trapeze integration method, 155–164 case of Romberg integration algorithm, 166 compared to other methods, 171 ending iteration, 157
t distribution. See Student distribution tensor products, 211, 214, 216, 224, 230 transposes of matrices, 211–212, 216, 221 trapeze integration method, 155–164 case of Romberg integration algorithm, 166 compared to other methods, 171 ending iteration, 157 Euler-Maclaurin formula, 155
t distribution. See Student distribution tensor products, 211, 214, 216, 224, 230 transposes of matrices, 211–212, 216, 221 trapeze integration method, 155–164 case of Romberg integration algorithm, 166 compared to other methods, 171 ending iteration, 157 Euler-Maclaurin formula, 155 general implementation,
t distribution. See Student distribution tensor products, 211, 214, 216, 224, 230 transposes of matrices, 211–212, 216, 221 trapeze integration method, 155–164 case of Romberg integration algorithm, 166 compared to other methods, 171 ending iteration, 157 Euler-Maclaurin formula, 155 general implementation, 157–158
t distribution. See Student distribution tensor products, 211, 214, 216, 224, 230 transposes of matrices, 211–212, 216, 221 trapeze integration method, 155–164 case of Romberg integration algorithm, 166 compared to other methods, 171 ending iteration, 157 Euler-Maclaurin formula, 155 general implementation, 157–158 Java implementation, 160–162
t distribution. See Student distribution tensor products, 211, 214, 216, 224, 230 transposes of matrices, 211–212, 216, 221 trapeze integration method, 155–164 case of Romberg integration algorithm, 166 compared to other methods, 171 ending iteration, 157 Euler-Maclaurin formula, 155 general implementation, 157–158 Java implementation, 160–162 partitioning, 155–156
t distribution. See Student distribution tensor products, 211, 214, 216, 224, 230 transposes of matrices, 211–212, 216, 221 trapeze integration method, 155–164 case of Romberg integration algorithm, 166 compared to other methods, 171 ending iteration, 157 Euler-Maclaurin formula, 155 general implementation, 157–158 Java implementation, 160–162 partitioning, 155–156 Smalltalk implementation,
t distribution. See Student distribution tensor products, 211, 214, 216, 224, 230 transposes of matrices, 211–212, 216, 221 trapeze integration method, 155–164 case of Romberg integration algorithm, 166 compared to other methods, 171 ending iteration, 157 Euler-Maclaurin formula, 155 general implementation, 157–158 Java implementation, 160–162 partitioning, 155–156 Smalltalk implementation, 158–160
t distribution. See Student distribution tensor products, 211, 214, 216, 224, 230 transposes of matrices, 211–212, 216, 221 trapeze integration method, 155–164 case of Romberg integration algorithm, 166 compared to other methods, 171 ending iteration, 157 Euler-Maclaurin formula, 155 general implementation, 157–158 Java implementation, 160–162 partitioning, 155–156 Smalltalk implementation,

```
Smalltalk implementation,
     430-431
UML (Unified Modeling
     Language), 2, 26
unbiased estimations, 457
uniform distribution, 671, 723-728
upper matrices, 257
value method, 36, 41
variances, 313, 316, 319-320, 325
  beta distribution, 672
  covariance. See covariance
     matrices
  estimated, 460
  exponential distribution, 688
  Fisher-Snedecor distribution,
     414
  Fisher-Tippet distribution, 695
  gamma distribution, 393
  Laplace distribution's, 703
  log normal distribution's, 710
  normal distribution, 385
  for probability density functions,
     369
  probability distributions, 369,
     371
  Student distribution, 426
  triangular distribution's, 717
  uniform distribution, 723
  Weibull distribution, 729
vector averages, 606-609, 611
Vector class, 150, 223, 669
vector functions
  maximums, finding, 552, 554,
  minimums, finding, 560, 563
  transforming to one-variable
     functions, 521-522, 536-539
   accumulate method, 214-215,
     225
  Array class, 213
  components, 209, 224
  defined, 209
  dot products, 210
  Java, 150, 222-231, 669
  in linear algebra, 243
```

multiplication, 212, 216

components, 616

with normal distribution of

```
norms, 210, 215
  operations on, 210
  optimizing classes, 527-531
  products with matrices, 211,
     216
  public interface for, 212, 222
  scalar products, 210
  Smalltalk classes for, 212-216
  tensor products, 211, 214, 216,
     224, 230
Visual Age for Java, 744
visual programming, 3
Weibull distribution, 728-735, 729
  Java implementation, 732-735
  properties, table of, 729
  Smalltalk implementation,
     730-732
weighted points
  equation for, 437
  general implementation,
     442-443
  Java implementation, 446-448
  Smalltalk implementation,
     444-445
zeroes of functions, 133-150
  bisection method, 134-140, 150
  Brent's method, 150
  class diagram for, 134
  continuity requirement, 134
  defined, 133
  inverse functions, 133
  Newton's method, 140-147,
     150
  regula falsi, 150
  roots of polynomials, 147-150
  searching for the extremes, 133
  speed of methods, 150
```

trigonometric functions, 178

in histograms, 357-358

relation to F-test, 427

Java implementation, 329–330

t-test, 198, 424-436

equation for, 425