MATLAB® / R Reference

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I wrote the first version of this reference during the Spring 2007 semester, as I learned R while teaching my course "MAT400, Modeling & Simulation" at the University of Maine. The course covers population and epidemiological modeling, including deterministic and stochastic models in discrete and continuous time, along with spatial models. Half of the class meetings are in a regular classroom, and half are in a computer lab where students work through modeling & simulation exercises. When I taught earlier versions of the course, it was based on Matlab only. In Spring 2007, some biology graduate students in the class who had learned R in statistics courses asked if they could use R in my class as well, and I said yes. My colleague Bill Halteman was a great help as I frantically learned R to stay ahead of the class. As I went, every time I learned how to do something in R for the course, I added it to this reference, so that I wouldn't forget it later. Some items took a huge amount of time searching for a simple way to do what I wanted, but at the end of the semester, I was pleasantly surprised that almost everything I do in Matlab had an equivalent in R. I was also inspired to do this after seeing the "R for Octave Users" reference written by Robin Hankin. I've continued to add to the document, with many additions based on topics that came up while teaching courses on Advanced Linear Algebra and Numerical Analysis.

This reference is organized into general categories. There is also a Matlab index and an R index at the end, which should make it easy to look up a command you know in one of the languages and learn how to do it in the other (or if you're trying to read code in whichever language is unfamiliar to you, allow you to translate back to the one you are more familiar with). The index entries refer to the item numbers in the first column of the reference document, rather than page numbers.

Any corrections, suggested improvements, or even just notification that the reference has been useful will be appreciated. I hope all the time I spent on this will prove useful for others in addition to myself and my students. Note that sometimes I don't necessarily do things in what you may consider the "best" way in a particular language; I often tried to do things in a similar way in both languages. But if you believe you have a "better" way (either simpler, or more computationally efficient) to do something, feel free to let me know.

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Contents

1 Help

No.	Description	MATLAB	R
1	Show help for a function (e.g. **sqrt**)	`help sqrt`, or `helpwin sqrt` to see it in a separate window	`help(sqrt)` or `?sqrt`
2	Show help for a built-in keyword (e.g. **for**)	`help for`	`help('for')` or `?'for'`
3	General list of many help topics	`help`	`library()` to see available libraries, or `library(help='base')` for very long list of stuff in base package which you can see help for
4	Explore main documentation in browser	`doc` or `helpbrowser` (previously it was `helpdesk`, which is now being phased out)	`help.start()`
5	Search documentation for keyword or partial keyword (e.g. functions which refer to "binomial")	`lookfor binomial`	`help.search('binomial')`

2 Entering/building/indexing matrices

No.	Description	MATLAB	R
6	Enter a row vector $\vec{v} = \begin{bmatrix} 1 & 2 & 3 & 4 \end{bmatrix}$	`v=[1 2 3 4]`	`v=c(1,2,3,4)` or alternatively `v=scan()` then enter "1 2 3 4" and press Enter twice (the blank line terminates input)
7	Enter a column vector $\begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \end{bmatrix}$	`[1; 2; 3; 4]`	`c(1,2,3,4)` (R does not distinguish between row and column vectors.)
8	Enter a matrix $\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix}$	`[1 2 3 ; 4 5 6]`	To enter values by row: `matrix(c(1,2,3,4,5,6), nrow=2, byrow=TRUE)` To enter values by column: `matrix(c(1,4,2,5,3,6), nrow=2)`
9	Access an element of vector **v**	`v(3)`	`v[3]`
10	Access an element of matrix **A**	`A(2,3)`	`A[2,3]`
11	Access an element of matrix **A** using a single index: indices count down the first column, then down the second column, etc.	`A(5)`	`A[5]`
12	Build the vector [2 3 4 5 6 7]	`2:7`	`2:7`
13	Build the vector [7 6 5 4 3 2]	`7:-1:2`	`7:2`
14	Build the vector [2 5 8 11 14]	`2:3:14`	`seq(2,14,3)`

No.	Description	MATLAB	R
15	Build a vector containing n equally-spaced values between a and b inclusive	`linspace(a,b,n)`	`seq(a,b,length.out=n)` or just `seq(a,b,len=n)`
16	Build a vector containing n logarithmically equally-spaced values between 10^a and 10^b inclusive	`logspace(a,b,n)`	`10^seq(a,b,len=n)`
17	Build a vector of length k containing all zeros	`zeros(k,1)` (for a column vector) or `zeros(1,k)` (for a row vector)	`rep(0,k)`
18	Build a vector of length k containing the value j in all positions	`j*ones(k,1)` (for a column vector) or `j*ones(1,k)` (for a row vector)	`rep(j,k)`
19	Build an $m \times n$ matrix of zeros	`zeros(m,n)`	`matrix(0,nrow=m,ncol=n)` or just `matrix(0,m,n)`
20	Build an $m \times n$ matrix containing j in all positions	`j*ones(m,n)`	`matrix(j,nrow=m,ncol=n)` or just `matrix(j,m,n)`
21	$n \times n$ identity matrix I_n	`eye(n)`	`diag(n)`
22	Build diagonal matrix A using elements of vector **v** as diagonal entries	`diag(v)`	`diag(v,nrow=length(v))` (Note: if you are sure the length of vector **v** is 2 or more, you can simply say `diag(v)`.)
23	Extract diagonal elements of matrix A	`v=diag(A)`	`v=diag(A)`
24	"Glue" two matrices **a1** and **a2** (with the same number of rows) side-by-side	`[a1 a2]`	`cbind(a1,a2)`
25	"Stack" two matrices **a1** and **a2** (with the same number of columns) on top of each other	`[a1; a2]`	`rbind(a1,a2)`
26	Reverse the order of elements in vector **v**	`v(end:-1:1)`	`rev(v)`
27	Column 2 of matrix **A**	`A(:,2)`	`A[,2]` Note: that gives the result as a vector. To make the result a $m \times 1$ matrix instead, do `A[,2,drop=FALSE]`
28	Row 7 of matrix **A**	`A(7,:)`	`A[7,]` Note: that gives the result as a vector. To make the result a $1 \times n$ matrix instead, do `A[7,,drop=FALSE]`
29	All elements of **A** as a vector, column-by-column	`A(:)` (gives a column vector)	`c(A)`
30	Rows 2–4, columns 6–10 of **A** (this is a 3×5 matrix)	`A(2:4,6:10)`	`A[2:4,6:10]`
31	A 3×2 matrix consisting of rows 7, 7, and 6 and columns 2 and 1 of A (in that order)	`A([7 7 6], [2 1])`	`A[c(7,7,6),c(2,1)]`

No.	Description	MATLAB	R
32	Given a single index **ind** into an $m \times n$ matrix **A**, compute the row **r** and column **c** of that position (also works if **ind** is a vector)	`[r,c] = ind2sub(size(A), ind)`	`r = ((ind-1) %% m) + 1` `c = floor((ind-1) / m) + 1`
33	Given the row **r** and column **c** of an element of an $m \times n$ matrix **A**, compute the single index **ind** which can be used to access that element of **A** (also works if **r** and **c** are vectors)	`ind = sub2ind(size(A), r, c)`	`ind = (c-1)*m + r`
34	Given equal-sized vectors **r** and **c** (each of length k), set elements in rows (given by **r**) and columns (given by **c**) of matrix **A** equal to 12. That is, k elements of A will be modified.	`inds = sub2ind(size(A),r,c);` `A(inds) = 12;`	`inds = cbind(r,c)` `A[inds] = 12`
35	Truncate vector **v**, keeping only the first 10 elements	`v = v(1:10)`	`v = v[1:10]`, or `length(v) = 10` also works
36	Extract elements of vector **v** from position **a** to the end	`v(a:end)`	`v[a:length(v)]`
37	All but the k^{th} element of vector **v**	`v([1:(k-1) (k+1):end])`	`v[-k]`
38	All but the j^{th} and k^{th} elements of vector **v**	No simple way? Generalize the previous item	`v[c(-j,-k)]`
39	Reshape matrix A, making it an $m \times n$ matrix with elements taken columnwise from the original A (which must have mn elements)	`A = reshape(A,m,n)`	`dim(A) = c(m,n)`
40	Extract the lower-triangular portion of matrix A	`L = tril(A)`	`L = A; L[upper.tri(L)]=0`
41	Extract the upper-triangular portion of matrix A	`U = triu(A)`	`U = A; U[lower.tri(U)]=0`
42	Enter $n \times n$ Hilbert matrix H where $H_{ij} = 1/(i+j-1)$	`hilb(n)`	`Hilbert(n)`, but this is part of the **Matrix** package which you'll need to install (see item 316 for how to install/load packages).
43	Enter an n-dimensional array, e.g. a $3 \times 4 \times 2$ array with the values 1 through 24	`reshape(1:24, 3, 4, 2)` or `reshape(1:24, [3 4 2])`	`array(1:24, c(3,4,2))` (Note that a **matrix** is 2-D, i.e. rows and columns, while an **array** is more generally N-D)

2.1 Cell arrays and lists

No.	Description	MATLAB	R

44	Build a vector **v** of length **n**, capable of containing different data types in different elements (called a *cell array* in MATLAB, and a *list* in R)	`v = cell(1,n)` In general, `cell(m,n)` makes an $m \times n$ cell array. Then you can do e.g.:
		`v{1} = 12`
		`v{2} = 'hi there'`
		`v{3} = rand(3)`
			`v = vector('list',n)` Then you can do e.g.:
			`v[[1]] = 12`
			`v[[2]] = 'hi there'`
			`v[[3]] = matrix(runif(9),3)`

45	Extract the i^{th} element of a cell/list vector **v**	`w = v{i}` If you use regular indexing, i.e. `w = v(i)`, then **w** will be a 1×1 cell matrix containing the contents of the i^{th} element of **v**.	`w = v[[i]]` If you use regular indexing, i.e. `w = v[i]`, then **w** will be a list of length 1 containing the contents of the i^{th} element of **v**.
46	Set the name of the i^{th} element in a list.	(MATLAB does not have names associated with elements of cell arrays.)	`names(v)[3] = 'myrandmatrix'` Use `names(v)` to see all names, and `names(v)=NULL` to clear all names.

2.2 Structs and data frames

No.	Description	MATLAB	R

47	Create a matrix-like object with different named columns (a *struct* in MATLAB, or a *data frame* in R)	`avals=2*ones(1,6);`
		`yvals=6:-1:1; v=[1 5 3 2 3 7];`
		`d=struct('a',avals,`
		` 'yy', yyvals, 'fac', v);`
			`v=c(1,5,3,2,3,7); d=data.frame(`
			`cbind(a=2, yy=6:1), v)`

Note that I (surprisingly) don't use R for statistics, and therefore have very little experience with data frames (and also very little with MATLAB structs). I will try to add more to this section later on.

3 Computations

3.1 Basic computations

No.	Description	MATLAB	R
48	$a+b$, $a-b$, ab, a/b	`a+b`, `a-b`, `a*b`, `a/b`	`a+b`, `a-b`, `a*b`, `a/b`
49	$\sqrt{a}$	`sqrt(a)`	`sqrt(a)`
50	a^b	`a^b`	`a^b`
51	$\lvert a\rvert$ (note: for complex arguments, this computes the modulus)	`abs(a)`	`abs(a)`
52	e^a	`exp(a)`	`exp(a)`
53	$\ln(a)$	`log(a)`	`log(a)`
54	$\log_2(a)$, $\log_{10}(a)$	`log2(a)`, `log10(a)`	`log2(a)`, `log10(a)`
55	$\sin(a)$, $\cos(a)$, $\tan(a)$	`sin(a)`, `cos(a)`, `tan(a)`	`sin(a)`, `cos(a)`, `tan(a)`
56	$\sin^{-1}(a)$, $\cos^{-1}(a)$, $\tan^{-1}(a)$	`asin(a)`, `acos(a)`, `atan(a)`	`asin(a)`, `acos(a)`, `atan(a)`
57	$\sinh(a)$, $\cosh(a)$, $\tanh(a)$	`sinh(a)`, `cosh(a)`, `tanh(a)`	`sinh(a)`, `cosh(a)`, `tanh(a)`
58	$\sinh^{-1}(a)$, $\cosh^{-1}(a)$, $\tanh^{-1}(a)$	`asinh(a)`, `acosh(a)`, `atanh(a)`	`asinh(a)`, `acosh(a)`, `atanh(a)`

No.	Description	MATLAB	R
59	n MOD k (modulo arithmetic)	`mod(n,k)`	`n %% k`
60	Round to nearest integer	`round(x)`	`round(x)` (Note: R uses IEC 60559 standard, rounding 5 to the even digit — so e.g. `round(0.5)` gives 0, not 1.)
61	Round down to next lowest integer	`floor(x)`	`floor(x)`
62	Round up to next largest integer	`ceil(x)`	`ceiling(x)`
63	Sign of x (+1, 0, or -1)	`sign(x)` (Note: for complex values, this computes `x/abs(x)`.)	`sign(x)` (Does not work with complex values)
64	Error function $\text{erf}(x) = (2/\sqrt{\pi})\int_0^x e^{-t^2}dt$	`erf(x)`	`2*pnorm(x*sqrt(2))-1`
65	Complementary error function $\text{cerf}(x) = (2/\sqrt{\pi})\int_x^\infty e^{-t^2}dt = 1\text{-erf}(x)$	`erfc(x)`	`2*pnorm(x*sqrt(2),lower=FALSE)`
66	Inverse error function	`erfinv(x)`	`qnorm((1+x)/2)/sqrt(2)`
67	Inverse complementary error function	`erfcinv(x)`	`qnorm(x/2,lower=FALSE)/sqrt(2)`
68	Binomial coefficient $\begin{pmatrix} n \\ k \end{pmatrix} = n!/(n!(n-k)!)$	`nchoosek(n,k)`	`choose(n,k)`

Note: the various functions above (logarithm, exponential, trig, abs, and rounding functions) all work with vectors and matrices, applying the function to each element, as well as with scalars.

3.2 Complex numbers

No.	Description	MATLAB	R
69	Enter a complex number	`1+2i`	`1+2i`
70	Modulus (magnitude)	`abs(z)`	`abs(z)` or `Mod(z)`
71	Argument (angle)	`angle(z)`	`Arg(z)`
72	Complex conjugate	`conj(z)`	`Conj(z)`
73	Real part of z	`real(z)`	`Re(z)`
74	Imaginary part of z	`imag(z)`	`Im(z)`

3.3 Matrix/vector computations

No.	Description	MATLAB	R
75	Matrix multiplication AB	`A * B`	`A %*% B`
76	Element-by-element multiplication of A and B	`A .* B`	`A * B`
77	Transpose of a matrix, A^T	`A'` (This is actually the complex conjugate (i.e. Hermitian) transpose; use `A.'` for the non-conjugate transpose if you like; they are equivalent for real matrices.)	`t(A)` for transpose, or `Conj(t(A))` for conjugate (Hermitian) transpose
78	Solve $A\vec{x} = \vec{b}$	`A\b` Warning: if there is no solution, MATLAB gives you a least-squares "best fit." If there are many solutions, MATLAB just gives you one of them.	`solve(A,b)` Warning: this only works with square invertible matrices.
79	Reduced echelon form of A	`rref(A)`	R does not have a function to do this
80	Compute inverse of **A**	`inv(A)`	`solve(A)`
81	Compute AB^{-1}	`A/B`	`A %*% solve(B)`
82	Element-by-element division of A and B	`A ./ B`	`A / B`
83	Compute $A^{-1}B$	`A\B`	`solve(A,B)`
84	Square the matrix A	`A^2`	`A %*% A`
85	Raise matrix A to the k^{th} power	`A^k`	(No easy way to do this in R other than repeated multiplication `A %*% A %*% A...`)
86	Raise each element of A to the k^{th} power	`A.^k`	`A^k`
87	Rank of matrix A	`rank(A)`	`qr(A)$rank`
88	Set **w** to be a vector of eigenvalues of **A**, and **V** a matrix containing the corresponding eigenvectors	`[V,D]=eig(A)` and then `w=diag(D)` since MATLAB returns the eigenvalues on the diagonal of **D**	`tmp=eigen(A); w=tmp$values; V=tmp$vectors`
89	Permuted LU factorization of a matrix	`[L,U,P]=lu(A)` then the matrices satisfy $PA = LU$. Note that this works even with non-square matrices	`tmp=expand(lu(Matrix(A))); L=tmp$L; U=tmp$U; P=tmp$P` then the matrices satisfy $A = PLU$, i.e. $P^{-1}A = LU$. Note that the **lu** and **expand** functions are part of the Matrix package (see item 316 for how to install/load packages). Also note that this doesn't seem to work correctly with non-square matrices. **L**, **U**, and **P** will be of class Matrix rather than class matrix; to make them the latter, instead do `L=as.matrix(tmp$L)`, `U=as.matrix(tmp$U)`, and `P=as.matrix(tmp$P)` above.

No.	Description	MATLAB	R
90	Singular-value decomposition: given $m \times n$ matrix A with rank r, find $m \times r$ matrix P with orthonormal columns, diagonal $r \times r$ matrix S, and $r \times n$ matrix Q^T with orthonormal rows so that $PSQ^T = A$	`[P,S,Q]=svd(A,'econ')`	`tmp=svd(A); U=tmp$u; V=tmp$v; S=diag(tmp$d)`
91	Schur decomposition of square matrix, $A = QTQ^H = QTQ^{-1}$ where Q is unitary (i.e. $Q^H Q = I$) and T is upper triangular; $Q^H = \overline{Q^T}$ is the Hermitian (conjugate) transpose	`[Q,T]=schur(A)`	`tmp=Schur(Matrix(A)); T=tmp@T; Q=tmp@Q` Note that **Schur** is part of the Matrix package (see item 316 for how to install/load packages). **T** and **Q** will be of class Matrix rather than class matrix; to make them the latter, instead do `T=as.matrix(tmp@T)` and `Q=as.matrix(tmp@Q)` above.
92	Cholesky factorization of a square, symmetric, positive definite matrix $A = R^T R$, where R is upper-triangular	`R = chol(A)`	`R = chol(A)` Note that **chol** is part of the Matrix package (see item 316 for how to install/load packages).
93	QR factorization of matrix A, where Q is orthogonal (satisfying $QQ^T = I$) and R is upper-triangular	`[Q,R]=qr(A)` satisfying $QR = A$, or `[Q,R,E]=qr(A)` to do permuted QR factorization satisfying $AE = QR$	`z=qr(A); Q=qr.Q(z); R=qr.R(z); E=diag(n)[,z$pivot]` (where **n** is the number of columns in A) gives permuted QR factorization satisfying $AE = QR$
94	Vector norms	`norm(v,1)` for 1-norm $\|\vec{v}\|_1$, `norm(v,2)` for Euclidean norm $\|\vec{v}\|_2$, `norm(v,inf)` for infinity-norm $\|\vec{v}\|_\infty$, and `norm(v,p)` for p-norm $\|\vec{v}\|_p = (\sum \|v_i\|^p)^{1/p}$	R does not have a **norm** function for vectors; only one for matrices. But the following will work: `norm(matrix(v),'1')` for 1-norm $\|\vec{v}\|_1$, `norm(matrix(v),'i')` for infinity-norm $\|\vec{v}\|_\infty$, and `sum(abs(v)^p)^(1/p)` for p-norm $\|\vec{v}\|_p = (\sum \|v_i\|^p)^{1/p}$
95	Matrix norms	`norm(A,1)` for 1-norm $\|A\|_1$, `norm(A)` for 2-norm $\|A\|_2$, `norm(A,inf)` for infinity-norm $\|A\|_\infty$, and `norm(A,'fro')` for Frobenius norm $\left(\sum_i (A^T A)_{ii}\right)^{1/2}$	`norm(A,'1')` for 1-norm $\|A\|_1$, `max(svd(A)$d)` for 2-norm $\|A\|_2$, `norm(A,'i')` for infinity-norm $\|A\|_\infty$, and `norm(A,'f')` for Frobenius norm $\left(\sum_i (A^T A)_{ii}\right)^{1/2}$
96	Condition number $\text{cond}(A) = \|A\|_1 \|A^{-1}\|_1$ of A, using 1-norm	`cond(A,1)` (Note: MATLAB also has a function `rcond(A)` which computes reciprocal condition estimator using the 1-norm)	`1/rcond(A,'1')`
97	Condition number $\text{cond}(A) = \|A\|_2 \|A^{-1}\|_2$ of A, using 2-norm	`cond(A,2)`	`kappa(A, exact=TRUE)` (leave out the "**exact=TRUE**" for an estimate)
98	Condition number $\text{cond}(A) = \|A\|_\infty \|A^{-1}\|_\infty$ of A, using infinity-norm	`cond(A,inf)`	`1/rcond(A,'I')`

No.	Description	MATLAB	R
99	Compute mean of all elements in vector or matrix	`mean(v)` for vectors, `mean(A(:))` for matrices	`mean(v)` or `mean(A)`
100	Compute means of columns of a matrix	`mean(A)`	`colMeans(A)`
101	Compute means of rows of a matrix	`mean(A,2)`	`rowMeans(A)`
102	Compute standard deviation of all elements in vector or matrix	`std(v)` for vectors, `std(A(:))` for matrices. This normalizes by $n-1$. Use `std(v,1)` to normalize by n.	`sd(v)` for vectors, `sd(c(A))` for matrices. This normalizes by $n-1$.
103	Compute standard deviations of columns of a matrix	`std(A)`. This normalizes by $n-1$. Use `std(A,1)` to normalize by n	`sd(A)`. This normalizes by $n-1$.
104	Compute standard deviations of rows of a matrix	`std(A,0,2)` to normalize by $n-1$, `std(A,1,2)` to normalize by n	`apply(A,1,sd)`. This normalizes by $n-1$.
105	Compute variance of all elements in vector or matrix	`var(v)` for vectors, `var(A(:))` for matrices. This normalizes by $n-1$. Use `var(v,1)` to normalize by n.	`var(v)` for vectors, `var(c(A))` for matrices. This normalizes by $n-1$.
106	Compute variance of columns of a matrix	`var(A)`. This normalizes by $n-1$. Use `var(A,1)` to normalize by n	`apply(A,2,var)`. This normalizes by $n-1$.
107	Compute variance of rows of a matrix	`var(A,0,2)` to normalize by $n-1$, `var(A,1,2)` to normalize by n	`apply(A,1,var)`. This normalizes by $n-1$.
108	Compute covariance for two vectors of observations	`cov(v,w)` computes the 2×2 covariance matrix; the off-diagonal elements give the desired covariance	`cov(v,w)`
109	Compute covariance matrix, giving covariances between columns of matrix A	`cov(A)`	`var(A)` or `cov(A)`
110	Given matrices A and B, build covariance matrix C where c_{ij} is the covariance between column i of A and column j of B	I don't know of a direct way to do this in Matlab. But one way is `[Y,X]=meshgrid(std(B),std(A));` `X.*Y.*corr(A,B)`	`cov(A,B)`
111	Compute Pearson's linear correlation coefficient between elements of vectors **v** and **w**	`corr(v,w)` Note: **v** and **w** must be column vectors. To make it work regardless of whether they are row or column vectors, do `corr(v(:),w(:))`	`cor(v,w)`
112	Compute Kendall's tau correlation statistic for vectors **v** and **w**	`corr(v,w,'type','kendall')`	`cor(v,w,method='kendall')`
113	Compute Spearman's rho correlation statistic for vectors **v** and **w**	`corr(v,w,'type','spearman')`	`cor(v,w,method='spearman')`
114	Compute pairwise Pearson's correlation coefficient between columns of matrix A	`corr(A)` The **'type'** argument may also be used as in the previous two items	`cor(A)` The **method** argument may also be used as in the previous two items
115	Compute matrix C of pairwise Pearson's correlation coefficients between each pair of columns of matrices A and B, i.e. so c_{ij} is the correlation between column i of A and column j of B	`corr(A,B)` The **'type'** argument may also be used as just above	`cor(A,B)` The **method** argument may also be used as just above

No.	Description	MATLAB	R
116	Compute sum of all elements in vector or matrix	`sum(v)` for vectors, `sum(A(:))` for matrices	`sum(v)` or `sum(A)`
117	Compute sums of columns of matrix	`sum(A)`	`colSums(A)`
118	Compute sums of rows of matrix	`sum(A,2)`	`rowSums(A)`
119	Compute matrix exponential $e^A = \sum_{k=0}^{\infty} A^k/k!$	`expm(A)`	`expm(Matrix(A))`, but this is part of the **Matrix** package which you'll need to install (see item 316 for how to install/load packages).
120	Compute cumulative sum of values in vector	`cumsum(v)`	`cumsum(v)`
121	Compute cumulative sums of columns of matrix	`cumsum(A)`	`apply(A,2,cumsum)`
122	Compute cumulative sums of rows of matrix	`cumsum(A,2)`	`t(apply(A,1,cumsum))`
123	Compute cumulative sum of all elements of matrix (column-by-column)	`cumsum(A(:))`	`cumsum(A)`
124	Cumulative product of elements in vector **v**	`cumprod(v)` (Can also be used in the various ways `cumsum` can)	`cumprod(v)` (Can also be used in the various ways `cumsum` can)
125	Cumulative minimum or maximum of elements in vector **v**	I don't know of an easy way to do this in MATLAB	`cummin(v)` or `cummax(v)`
126	Compute differences between consecutive elements of vector **v**. Result is a vector **w** 1 element shorter than **v**, where element i of **w** is element $i+1$ of **v** minus element i of **v**	`diff(v)`	`diff(v)`
127	Make a vector **y** the same size as vector **x**, which equals **4** everywhere that **x** is greater than 5, and equals 3 everywhere else (done via a vectorized computation).	`z = [3 4]; y = z((x > 5)+1)`	`y = ifelse(x > 5, 4, 3)`
128	Compute minimum of values in vector **v**	`min(v)`	`min(v)`
129	Compute minimum of all values in matrix **A**	`min(A(:))`	`min(A)`
130	Compute minimum value of each column of matrix **A**	`min(A)` (returns a row vector)	`apply(A,2,min)` (returns a vector)
131	Compute minimum value of each row of matrix **A**	`min(A, [ ], 2)` (returns a column vector)	`apply(A,1,min)` (returns a vector)

No.	Description	Matlab	R
132	Given matrices **A** and **B**, compute a matrix where each element is the minimum of the corresponding elements of **A** and **B**	`min(A,B)`	`pmin(A,B)`
133	Given matrix **A** and scalar **c**, compute a matrix where each element is the minimum of **c** and the corresponding element of **A**	`min(A,c)`	`pmin(A,c)`
134	Find minimum among all values in matrices **A** and **B**	`min([A(:)  ; B(:)])`	`min(A,B)`
135	Find index of the first time `min(v)` appears in **v**, and store that index in **ind**	`[y,ind] = min(v)`	`ind = which.min(v)`

Notes:

- Matlab and R both have a `max` function (and R has `pmax` and `which.max` as well) which behaves in the same ways as `min` but to compute maxima rather than minima.
- Functions like `exp`, `sin`, `sqrt` etc. will operate on arrays in both Matlab and R, doing the computations for each element of the matrix.

No.	Description	Matlab	R
136	Number of rows in A	`size(A,1)`	`nrow(A)`
137	Number of columns in A	`size(A,2)`	`ncol(A)`
138	Dimensions of A, listed in a vector	`size(A)`	`dim(A)`
139	Number of elements in vector **v**	`length(v)`	`length(v)`
140	Total number of elements in matrix A	`numel(A)`	`length(A)`
141	Max. dimension of A	`length(A)`	`max(dim(A))`
142	Sort values in vector **v**	`sort(v)`	`sort(v)`
143	Sort values in **v**, putting sorted values in **s**, and indices in **idx**, in the sense that **s**[**k**] = **x**[**idx**[**k**]]	`[s,idx]=sort(v)`	`tmp=sort(v,index.return=TRUE);` `s=tmp$x; idx=tmp$ix`
144	Sort the order of the rows of matrix **m**	`sortrows(m)` This sorts according to the first column, then uses column 2 to break ties, then column 3 for remaining ties, etc. Complex numbers are sorted by **abs(x)**, and ties are then broken by **angle(x)**.	`m[order(m[,1]),]` This only sorts according to the first column. To use column 2 to break ties, and then column 3 to break further ties, do `m[order(m[,1], m[,2], m[,3]),]` Complex numbers are sorted first by real part, then by imaginary part.
145	Sort order of rows of matrix **m**, specifying to use columns **c1**, **c2**, **c3** as the sorting "keys"	`sortrows(m, [c1 c2 c2])`	`m[order(m[,c1], m[,c2], m[,c3]),]`

No.	Description	MATLAB	R
146	Same as previous item, but sort in decreasing order for columns **c1** and **c2**	`sortrows(m, [-c1 -c2 c2])`	`m[order(-m[,c1], -m[,c2], m[,c3]),]`
147	Sort order of rows of matrix **m**, and keep indices used for sorting	`[y,i] = sortrows(m)`	`i=order(m[1,]); y=m[i,]`
148	To count how many values in the vector **v** are between 4 and 7 (inclusive on the upper end)	`sum((v > 4) & (v <= 7))`	`sum((v > 4) & (v <= 7))`
149	Given vector **v**, return list of indices of elements of **v** which are greater than 5	`find(v > 5)`	`which(v > 5)`
150	Given matrix **A**, return list of indices of elements of **A** which are greater than 5, using single-indexing	`find(A > 5)`	`which(A > 5)`
151	Given matrix **A**, generate vectors **r** and **c** giving rows and columns of elements of **A** which are greater than 5	`[r,c] = find(A > 5)`	`w = which(A > 5, arr.ind=TRUE); r=w[,1]; c=w[,2]`
152	Given vector **x** (of presumably discrete values), build a vector **v** listing unique values in **x**, and corresponding vector **c** indicating how many times those values appear in **x**	`v = unique(x); c = hist(x,v);`	`w=table(x); c=as.numeric(w); v=as.numeric(names(w))`
153	Given vector **x** (of presumably continuous values), divide the range of values into k equally-sized bins, and build a vector **m** containing the midpoints of the bins and a corresponding vector **c** containing the counts of values in the bins	`[c,m] = hist(x,k)`	`w=hist(x,seq(min(x),max(x), length.out=k+1), plot=FALSE); m=w$mids; c=w$counts`
154	Convolution / polynomial multiplication (given vectors **x** and **y** containing polynomial coefficients, their convolution is a vector containing coefficients of the product of the two polynomials)	`conv(x,y)`	`convolve(x,rev(y),type='open')` Note: the accuracy of this is not as good as MATLAB; e.g. doing `v=c(1,-1); for (i in 2:20) v=convolve(v,c(-i,1), type='open')` to generate the 20^{th}-degree Wilkinson polynomial $W(x)=\prod_{i=1}^{20}(x-i)$ gives a coefficient of ≈ -780.19 for x^{19}, rather than the correct value -210.

3.4 Root-finding

No.	Description	MATLAB	R
155	Find roots of polynomial whose coefficients are stored in vector **v** (coefficients in **v** are highest-order first)	`roots(v)`	`polyroot(rev(v))` (This function really wants the vector to have the constant coefficient first in **v**; `rev` reverses their order to achieve this.)
156	Find zero (root) of a function $f(x)$ of one variable	Define function **f(x)**, then do `fzero(f,x0)` to search for a root near **x0**, or `fzero(f,[a b])` to find a root between a and b, assuming the sign of $f(x)$ differs at $x = a$ and $x = b$. Default forward error tolerance (i.e. error in x) is machine epsilon ϵ_{mach}.	Define function **f(x)**, then do `uniroot(f, c(a,b))` to find a root between a and b, assuming the sign of $f(x)$ differs at $x = a$ and $x = b$. Default forward error tolerance (i.e. error in x) is fourth root of machine epsilon, $(\epsilon_{\mathrm{mach}})^{0.25}$. To specify e.g. a tolerance of 2^{-52}, do `uniroot(f, c(a,b), tol=2^-52)`.

3.5 Function optimization/minimization

No.	Description	MATLAB	R
157	Find value m which minimizes a function $f(x)$ of one variable within the interval from a to b	Define function **f(x)**, then do `m = fminbnd(f, a, b)`	Define function **f(x)**, then do `m = optimize(f,c(a,b))$minimum`

158	Find value m which minimizes a function $f(x, p_1, p_2)$ with given extra parameters (but minimization is only occuring over the first argument), in the interval from a to b.	Define function **f(x,p1,p2)**, then use an "anonymous function":
		`% first define values for p1`
		`% and p2, and then do:`
		`m=fminbnd(@(x) f(x,p1,p2),a,b)`
			Define function **f(x,p1,p2)**, then:
			`# first define values for p1`
			`# and p2, and then do:`
			`m = optimize(f, c(a,b), p1=p1,`
			`  p2=p2)$minimum`

159	Find values of x, y, z which minimize function $f(x, y, z)$, using a starting guess of $x = 1$, $y = 2.2$, and $z = 3.4$.	First write function **f(v)** which accepts a vector argument **v** containing values of x, y, and z, and returns the scalar value $f(x, y, z)$, then do: `fminsearch(@f,[1 2.2 3.4])`	First write function **f(v)** which accepts a vector argument **v** containing values of x, y, and z, and returns the scalar value $f(x, y, z)$, then do: `optim(c(1,2.2,3.4),f)$par`

160	Find values of x, y, z which minimize function $f(x, y, z, p_1, p_2)$, using a starting guess of $x = 1$, $y = 2.2$, and $z = 3.4$, where the function takes some extra parameters (useful e.g. for doing things like nonlinear least-squares optimization where you pass in some data vectors as extra parameters).	First write function **f(v,p1,p2)** which accepts a vector argument **v** containing values of x, y, and z, along with the extra parameters, and returns the scalar value $f(x, y, z, p_1, p_2)$, then do:
		`fminsearch(@f,[1 2.2 3.4], ...`
		`  [ ], p1, p2)`
		Or use an anonymous function:
		`fminsearch(@(x) f(x,p1,p2), ...`
		`  [1 2.2 3.4])`
			First write function **f(v,p1,p2)** which accepts a vector argument **v** containing values of x, y, and z, along with the extra parameters, and returns the scalar value $f(x, y, z, p_1, p_2)$, then do:
			`optim(c(1,2.2,3.4), f, p1=p1,`
			`  p2=p2)$par`

3.6 Numerical integration / quadrature

No.	Description	MATLAB	R
161	Numerically integrate function $f(x)$ over interval from a to b	`quad(f,a,b)` uses adaptive Simpson's quadrature, with a default absolute tolerance of 10^{-6}. To specify absolute tolerance, use `quad(f,a,b,tol)`	`integrate(f,a,b)` uses adaptive quadrature with default absolute and relative error tolerances being the fourth root of machine epsilon, $(\epsilon_{\mathrm{mach}})^{0.25} \approx 1.22 \times 10^{-4}$. Tolerances can be specified by using `integrate(f,a,b, rel.tol=tol1, abs.tol=tol2)`. Note that the function **f** must be written to work even when given a vector of x values as its argument.
162	Simple trapezoidal numerical integration using (x, y) values in vectors **x** and **y**	`trapz(x,y)`	`sum(diff(x)*(y[-length(y)]+ y[-1])/2)`

3.7 Curve fitting

No.	Description	MATLAB	R
163	Fit the line $y = c_1x + c_0$ to data in vectors **x** and **y**.	`p = polyfit(x,y,1)` The return vector **p** has the coefficients in descending order, i.e. **p(1)** is c_1, and **p(2)** is c_0.	`p = coef(lm(y ~ x))` The return vector **p** has the coefficients in ascending order, i.e. **p[1]** is c_0, and **p[2]** is c_1.
164	Fit the quadratic polynomial $y = c_2x^2 + c_1x + c_0$ to data in vectors **x** and **y**.	`p = polyfit(x,y,2)` The return vector **p** has the coefficients in descending order, i.e. **p(1)** is c_2, **p(2)** is c_1, and **p(3)** is c_0.	`p = coef(lm(y ~ x + I(x^2)))` The return vector **p** has the coefficients in ascending order, i.e. **p[1]** is c_0, **p[2]** is c_1, and **p[3]** is c_2.
165	Fit n^{th} degree polynomial $y = c_nx^n + c_{n-1}x^{n-1} + \ldots + c_1x + c_0$ to data in vectors **x** and **y**.	`p = polyfit(x,y,n)` The return vector **p** has the coefficients in descending order, **p(1)** is c^n, **p(2)** is c^{n-1}, etc.	There isn't a simple function built into the standard R distribution to do this, but see the **polyreg** function in the **mda** package (see item 316 for how to install/load packages).
166	Fit the quadratic polynomial with zero intercept, $y = c_2x^2 + c_1x$ to data in vectors **x** and **y**.	(I don't know a simple way do this in MATLAB, other than to write a function which computes the sum of squared residuals and use **fminsearch** on that function. There is likely an easy way to do it in the Statistics Toolbox.)	`p=coef(lm(y ~ -1 + x + I(x^2)))` The return vector **p** has the coefficients in ascending order, i.e. **p[1]** is c_1, and **p[2]** is c_2.
167	Fit natural cubic spline ($S''(x) = 0$ at both endpoints) to points (x_i, y_i) whose coordinates are in vectors **x** and **y**; evaluate at points whose x coordinates are in vector **xx**, storing corresponding y's in **yy**	`pp=csape(x,y,'variational');` `yy=ppval(pp,xx)` but note that **csape** is in MATLAB's Spline Toolbox	`tmp=spline(x,y,method='natural',` `xout=xx); yy=tmp$y`
168	Fit cubic spline using Forsythe, Malcolm and Moler method (third derivatives at endpoints match third derivatives of exact cubics through the four points at each end) to points (x_i, y_i) whose coordinates are in vectors **x** and **y**; evaluate at points whose x coordinates are in vector **xx**, storing corresponding y's in **yy**	I'm not aware of a function to do this in MATLAB	`tmp=spline(x,y,xout=xx);` `yy=tmp$y`

No.	Description	Matlab	R
169	Fit cubic spline such that first derivatives at endpoints match first derivatives of exact cubics through the four points at each end) to points (x_i, y_i) whose coordinates are in vectors **x** and **y**; evaluate at points whose x coordinates are in vector **xx**, storing corresponding y's in **yy**	`pp=csape(x,y); yy=ppval(pp,xx)` but **csape** is in Matlab's Spline Toolbox	I'm not aware of a function to do this in R
170	Fit cubic spline with periodic boundaries, i.e. so that first and second derivatives match at the left and right ends (the first and last y values of the provided data should also agree), to points (x_i, y_i) whose coordinates are in vectors **x** and **y**; evaluate at points whose x coordinates are in vector **xx**, storing corresponding y's in **yy**	`pp=csape(x,y,'periodic'); yy=ppval(pp,xx)` but **csape** is in Matlab's Spline Toolbox	`tmp=spline(x,y,method= 'periodic', xout=xx); yy=tmp$y`
171	Fit cubic spline with "not-a-knot" conditions (the first two piecewise cubics coincide, as do the last two), to points (x_i, y_i) whose coordinates are in vectors **x** and **y**; evaluate at points whose x coordinates are in vector **xx**, storing corresponding y's in **yy**	`yy=spline(x,y,xx)`	I'm not aware of a function to do this in R

4 Conditionals, control structure, loops

No.	Description	Matlab	R

172	"for" loops over values in a vector **v** (the vector **v** is often constructed via **a:b**)	`for i=v`
		`  command1`
		`  command2`
		`end`
			If only one command inside the loop:
			`for (i in v)`
			`  command`
			or
			`for (i in v) command`
			If multiple commands inside the loop:
			`for (i in v) {`
			`  command1`
			`  command2`
			`}`

No.	Description	MATLAB	R

173	"if" statements with no else clause	`if cond`
		`  command1`
		`  command2`
		`end`
			If only one command inside the clause:
			`if (cond)`
			`  command`
			or
			`if (cond) command`
			If multiple commands:
			`if (cond) {`
			`  command1`
			`  command2`
			`}`

174	"if/else" statement	`if cond`
		`  command1`
		`  command2`
		`else`
		`  command3`
		`  command4`
		`end`
		Note: MATLAB also has an "**elseif**" statement, e.g.:
		`if cond1`
		`  command1`
		`elseif cond2`
		`  command2`
		`elseif cond3`
		`  command3`
		`else`
		`  command4`
		`end`
			If one command in clauses:
			`if (cond)`
			`  command1 else`
			`  command2`
			or
			`if (cond) cmd1 else cmd2`
			If multiple commands:
			`if (cond) {`
			`  command1`
			`  command2`
			`} else {`
			`  command3`
			`  command4`
			`}`
			Warning: the "else" must be on the same line as `command1` or the "`}`" (when typed interactively at the command prompt), otherwise R thinks the "if" statement was finished and gives an error.
			R does not have an "**elseif**" statement.

Logical comparisons which can be used on scalars in "`if`" statements, or which operate element-by-element on vectors/matrices:

MATLAB	R	Description
x < a	**x < a**	True if x is less than a
x > a	**x > a**	True if x is greater than a
x <= a	**x <= a**	True if x is less than or equal to a
x >= a	**x >= a**	True if x is greater than or equal to a
x == a	**x == a**	True if x is equal to a
x ~= a	**x != a**	True if x is not equal to a

Scalar logical operators:

<table>
<tr><td>Description</td><td>MATLAB</td><td>R</td></tr>
<tr><td>a AND b</td><td><code>a && b</code></td><td><code>a && b</code></td></tr>
<tr><td>a OR b</td><td><code>a || b</code></td><td><code>a || b</code></td></tr>
<tr><td>a XOR b</td><td><code>xor(a,b)</code></td><td><code>xor(a,b)</code></td></tr>
<tr><td>NOT a</td><td><code>~a</code></td><td><code>!a</code></td></tr>
</table>

The `&&` and `||` operators are short-circuiting, i.e. `&&` stops as soon as any of its terms are FALSE, and `||` stops as soon as any of its terms are TRUE.

Matrix logical operators (they operate element-by-element):

<table>
<tr><td>Description</td><td>MATLAB</td><td>R</td></tr>
<tr><td>a AND b</td><td><code>a & b</code></td><td><code>a & b</code></td></tr>
<tr><td>a OR b</td><td><code>a | b</code></td><td><code>a | b</code></td></tr>
<tr><td>a XOR b</td><td><code>xor(a,b)</code></td><td><code>xor(a,b)</code></td></tr>
<tr><td>NOT a</td><td><code>~a</code></td><td><code>!a</code></td></tr>
</table>

No.	Description	MATLAB	R
175	To test whether a scalar value **x** is between 4 and 7 (inclusive on the upper end)	`if ((x > 4) && (x <= 7))`	`if ((x > 4) && (x <= 7))`
176	To count how many values in the vector **x** are between 4 and 7 (inclusive on the upper end)	`sum((x > 4) & (x <= 7))`	`sum((x > 4) & (x <= 7))`
177	Test whether all values in a logical/boolean vector are TRUE	`all(v)`	`all(v)`
178	Test whether any values in a logical/boolean vector are TRUE	`any(v)`	`any(v)`

No.	Description	Matlab	R

179	"while" statements to do iteration (useful when you don't know ahead of time how many iterations you'll need). E.g. to add uniform random numbers between 0 and 1 (and their squares) until their sum is greater than 20:	`mysum = 0;`
		`mysumsqr = 0;`
		`while (mysum < 20)`
		`  r = rand;`
		`  mysum = mysum + r;`
		`  mysumsqr = mysumsqr + r^2;`
		`end`
			`mysum = 0`
			`mysumsqr = 0`
			`while (mysum < 20) {`
			`  r = runif(1)`
			`  mysum = mysum + r`
			`  mysumsqr = mysumsqr + r^2`
			`}`
			
			(As with "if" statements and "for" loops, the curly brackets are not necessary if there's only one statement inside the "while" loop.)

180	More flow control: these commands exit or move on to the next iteration of the innermost **while** or **for** loop, respectively.	`break` and `continue`	`break` and `next`

181	"Switch" statements for integers	`switch (x)`
		`  case 10`
		`    disp('ten')`
		`  case {12,13}`
		`    disp('dozen (bakers?)')`
		`  otherwise`
		`    disp('unrecognized')`
		`end`
			R doesn't have a **switch** statement capable of doing this. It has a function which is fairly limited for integers, but can which do string matching. See `?switch` for more. But a basic example of what it can do for integers is below, showing that you can use it to return different expressions based on whether a value is $1, 2, \ldots$.
			
			`mystr = switch(x, 'one', 'two',`
			`  'three');  print(mystr)`
			
			Note that **switch** returns NULL if **x** is larger than 3 in the above case. Also, continuous values of **x** will be truncated to integers.

5 Functions, ODEs

No.	Description	MATLAB	R

182	Implement a function **add(x,y)**	Put the following in **add.m**:
		
		`function retval=add(x,y)`
		`retval = x+y;`
		
		Then you can do e.g. `add(2,3)`
			Enter the following, or put it in a file and **source** that file:
			
			`add = function(x,y) {`
			`  return(x+y)`
			`}`
			
			Then you can do e.g. `add(2,3)`. Note, the curly brackets aren't needed if your function only has one line. Also, the **return** keyword is optional in the above example, as the value of the last expression in a function gets returned, so just **x+y** would work too.

183	Implement a function **f(x,y,z)** which returns multiple values, and store those return values in variables **u** and **v**	Write function as follows:
		
		`function [a,b] = f(x,y,z)`
		`  a = x*y+z;  b=2*sin(x-z);`
		
		Then call the function by doing: `[u,v] = f(2,8,12)`
			Write function as follows:
			
			`f = function(x,y,z) {`
			`  a = x*y+z;  b=2*sin(x-z)`
			`  return(list(a,b))`
			`}`
			
			Then call the function by doing: `tmp=f(2,8,12); u=tmp[[1]]; v=tmp[[2]]`. The above is most general, and will work even when **u** and **v** are different types of data. If they are both scalars, the function could simply return them packed in a vector, i.e. `return(c(a,b))`. If they are vectors of the same size, the function could return them packed together into the columns of a matrix, i.e. `return(cbind(a,b))`.

No.	Description	Matlab	R

184	Numerically solve ODE $dx/dt = 5x$ from $t = 3$ to $t = 12$ with initial condition $x(3) = 7$	First implement function
		`function retval=f(t,x)`
		`retval = 5*x;`
		Then do `ode45(@f,[3,12],7)` to plot solution, or `[t,x]=ode45(@f,[3,12],7)` to get back vector **t** containing time values and vector **x** containing corresponding function values. If you want function values at specific times, e.g. $3, 3.1, 3.2, \ldots, 11.9, 12$, you can do `[t,x]=ode45(@f,3:0.1:12,7)`. Note: in older versions of Matlab, use `'f'` instead of `@f`.
			First implement function
			`f = function(t,x,parms) {`
			`return(list(5*x))`
			`}`
			Then do `y=lsoda(7, seq(3,12, 0.1), f,NA)` to obtain solution values at times $3, 3.1, 3.2, \ldots, 11.9, 12$. The first column of **y**, namely **y[,1]** contains the time values; the second column **y[,2]** contains the corresponding function values. Note: **lsoda** is part of the **deSolve** package (see item 316 for how to install/load packages).

185	Numerically solve system of ODEs $dw/dt = 5w$, $dz/dt = 3w + 7z$ from $t = 3$ to $t = 12$ with initial conditions $w(3) = 7$, $z(3) = 8.2$	First implement function
		`function retval=myfunc(t,x)`
		`w = x(1);  z = x(2);`
		`retval = zeros(2,1);`
		`retval(1) = 5*w;`
		`retval(2) = 3*w + 7*z;`
		Then do `ode45(@myfunc,[3,12],[7; 8.2])` to plot solution, or `[t,x]=ode45(@myfunc,[3,12],[7; 8.2])` to get back vector **t** containing time values and matrix **x**, whose first column containing corresponding $w(t)$ values and second column contains $z(t)$ values. If you want function values at specific times, e.g. $3, 3.1, 3.2, \ldots, 11.9, 12$, you can do `[t,x]=ode45(@myfunc,3:0.1:12,[7; 8.2])`. Note: in older versions of Matlab, use `'f'` instead of `@f`.
			First implement function
			`myfunc = function(t,x,parms) {`
			`w = x[1];  z = x[2];`
			`return(list(c(5*w, 3*w+7*z)))`
			`}`
			Then do `y=lsoda(c(7,8.2), seq(3,12, 0.1), myfunc,NA)` to obtain solution values at times $3, 3.1, 3.2, \ldots, 11.9, 12$. The first column of **y**, namely **y[,1]** contains the time values; the second column **y[,2]** contains the corresponding values of $w(t)$; and the third column contains $z(t)$. Note: **lsoda** is part of the **deSolve** package (see item 316 for how to install/load packages).

186	Pass parameters such as $r = 1.3$ and $K = 50$ to an ODE function from the command line, solving $dx/dt = rx(1 - x/K)$ from $t = 0$ to $t = 20$ with initial condition $x(0) = 2.5$.	First implement function
		`function retval=func2(t,x,r,K)`
		`retval = r*x*(1-x/K)`
		Then do `ode45(@func2,[0 20], 2.5, [ ], 1.3, 50)`. The empty matrix is necessary between the initial condition and the beginning of your extra parameters.
			First implement function
			`func2=function(t,x,parms) {`
			` r=parms[1];  K=parms[2]`
			` return(list(r*x*(1-x/K)))`
			`}`
			Then do
			`y=lsoda(2.5,seq(0,20,0.1),`
			` func2,c(1.3,50))`
			Note: **lsoda** is part of the **deSolve** package (see item 316 for how to install/load packages).

6 Probability and random values

No.	Description	MATLAB	R
187	Generate a continuous uniform random value between 0 and 1	`rand`	`runif(1)`
188	Generate vector of n uniform random vals between 0 and 1	`rand(n,1)` or `rand(1,n)`	`runif(n)`
189	Generate $m \times n$ matrix of uniform random values between 0 and 1	`rand(m,n)`	`matrix(runif(m*n),m,n)` or just `matrix(runif(m*n),m)`
190	Generate $m \times n$ matrix of continuous uniform random values between a and b	`a+rand(m,n)*(b-a)` or if you have the Statistics toolbox then `unifrnd(a,b,m,n)`	`matrix(runif(m*n,a,b),m)`
191	Generate a random integer between 1 and k	`floor(k*rand) + 1`	`floor(k*runif(1)) + 1` Note: `sample(k)[1]` would also work, but I believe in general will be less efficient, because that actually generates many random numbers and then just uses one of them.
192	Generate $m \times n$ matrix of discrete uniform random integers between 1 and k	`floor(k*rand(m,n))+1` or if you have the Statistics toolbox then `unidrnd(k,m,n)`	`floor(k*matrix(runif(m*n),m))+1`
193	Generate $m \times n$ matrix where each entry is 1 with probability p, otherwise is 0	`(rand(m,n)<p)*1` Note: multiplying by 1 turns the logical (true/false) result back into numeric values. You could also do `double(rand(m,n)<p)`	`(matrix(runif(m,n),m)<p)*1` (Note: multiplying by 1 turns the logical (true/false) result back into numeric values; using **as.numeric()** to do it would lose the shape of the matrix.)
194	Generate $m \times n$ matrix where each entry is a with probability p, otherwise is b	`b + (a-b)*(rand(m,n)<p)`	`b + (a-b)*(matrix(` `runif(m,n),m)<p)`
195	Generate a random integer between a and b inclusive	`floor((b-a+1)*rand)+a` or if you have the Statistics toolbox then `unidrnd(b-a+1)+a-1`	`floor((b-a+1)*runif(1))+a`

196	Flip a coin which comes up heads with probability p, and perform some action if it does come up heads	`if (rand < p)`
		`  ...some commands...`
		`end`
			`if (runif(1) < p) {`
			`  ...some commands...`
			`}`

197	Generate a random permutation of the integers $1, 2, \ldots, n$	`randperm(n)`	`sample(n)`
198	Generate a random selection of k unique integers between 1 and n (i.e. sampling without replacement)	`[s,idx]=sort(rand(n,1));` `ri=idx(1:k)` or another way is `ri=randperm(n); ri=ri(1:k)`. Or if you have the Statistics Toolbox, then `randsample(n,k)`	`ri=sample(n,k)`
199	Choose k values (with replacement) from the vector $\mathbf{v}$, storing result in $\mathbf{w}$	`L=length(v);` `w=v(floor(L*rand(k,1))+1)` Or, if you have the Statistics Toolbox, `w=randsample(v,k,replace=true)`	`w=sample(v,k,replace=TRUE)`

No.	Description	MATLAB	R
200	Choose k values (without replacement) from the vector **v**, storing result in **w**	`L=length(v); ri=randperm(L); ri=ri(1:k); w=v(ri)` Or, if you have the Statistics Toolbox, `w=randsample(v,k,replace=false)`	`w=sample(v,k,replace=FALSE)`
201	Set the random-number generator back to a known state (useful to do at the beginning of a stochastic simulation when debugging, so you'll get the same sequence of random numbers each time)	`rand('state', 12)` Note: beginning in Matlab 7.7, use this instead: `RandStream('mt19937ar', 'Seed', 12)` though the previous method is still supported for now.	`set.seed(12)`

Note that the "*rnd," "*pdf," and "*cdf" functions described below are all part of the MATLAB Statistics Toolbox, and not part of the core MATLAB distribution.

No.	Description	MATLAB	R
202	Generate a random value from the binomial(n, p) distribution	`binornd(n,p)`	`rbinom(1,n,p)`
203	Generate a random value from the Poisson distribution with parameter λ	`poissrnd(lambda)`	`rpois(1,lambda)`
204	Generate a random value from the exponential distribution with mean μ	`exprnd(mu)` or `-mu*log(rand)` will work even without the Statistics Toolbox.	`rexp(1, 1/mu)`
205	Generate a random value from the discrete uniform distribution on integers $1 \ldots k$	`unidrnd(k)` or `floor(rand*k)+1` will work even without the Statistics Toolbox.	`sample(k,1)`
206	Generate n iid random values from the discrete uniform distribution on integers $1 \ldots k$	`unidrnd(k,n,1)` or `floor(rand(n,1)*k)+1` will work even without the Statistics Toolbox.	`sample(k,n,replace=TRUE)`
207	Generate a random value from the continuous uniform distribution on the interval (a, b)	`unifrnd(a,b)` or `(b-a)*rand + a` will work even without the Statistics Toolbox.	`runif(1,a,b)`
208	Generate a random value from the normal distribution with mean μ and standard deviation σ	`normrnd(mu,sigma)` or `mu + sigma*randn` will work even without the Statistics Toolbox.	`rnorm(1,mu,sigma)`
209	Generate a random vector from the multinomial distribution, with **n** trials and probability vector **p**	`mnrnd(n,p)`	`rmultinom(1,n,p)`
210	Generate **j** random vectors from the multinomial distribution, with **n** trials and probability vector **p**	`mnrnd(n,p,j)` The vectors are returned as rows of a matrix	`rmultinom(j,n,p)` The vectors are returned as columns of a matrix

Notes:

- The MATLAB "*rnd" functions above can all take additional **r,c** arguments to build an $r \times c$ matrix of iid random values. E.g. `poissrnd(3.5,4,7)` for a 4×7 matrix of iid values from the Poisson distribution with mean $\lambda = 3.5$. The `unidrnd(k,n,1)` command above is an example of this, to generate a $k \times 1$ column vector.

- The first parameter of the R "r*" functions above specifies how many values are desired. E.g. to generate 28 iid random values from a Poisson distribution with mean 3.5, use `rpois(28,3.5)`. To get a 4×7 matrix of such values, use `matrix(rpois(28,3.5),4)`.

No.	Description	MATLAB	R
211	Compute probability that a random variable from the Binomial(n, p) distribution has value **x** (i.e. the density, or pdf).	`binopdf(x,n,p)` or `nchoosek(n,x)*p^x*(1-p)^(n-x)` will work even without the Statistics Toolbox, as long as **n** and **x** are non-negative integers and 0 ≤ **p** ≤ 1.	`dbinom(x,n,p)`
212	Compute probability that a random variable from the Poisson(λ) distribution has value **x**.	`poisspdf(x,lambda)` or `exp(-lambda)*lambda^x / factorial(x)` will work even without the Statistics Toolbox, as long as **x** is a non-negative integer and **lambda** ≥ 0.	`dpois(x,lambda)`
213	Compute probability density function at **x** for a random variable from the exponential distribution with mean μ.	`exppdf(x,mu)` or `(x>=0)*exp(-x/mu)/mu` will work even without the Statistics Toolbox, as long as **mu** is positive.	`dexp(x,1/mu)`
214	Compute probability density function at **x** for a random variable from the Normal distribution with mean μ and standard deviation σ.	`normpdf(x,mu,sigma)` or `exp(-(x-mu)^2/(2*sigma^2))/ (sqrt(2*pi)*sigma)` will work even without the Statistics Toolbox.	`dnorm(x,mu,sigma)`
215	Compute probability density function at **x** for a random variable from the continuous uniform distribution on interval (a, b).	`unifpdf(x,a,b)` or `((x>=a)&&(x<=b))/(b-a)` will work even without the Statistics Toolbox.	`dunif(x,a,b)`
216	Compute probability that a random variable from the discrete uniform distribution on integers $1 \ldots n$ has value **x**.	`unidpdf(x,n)` or `((x==floor(x)) && (x>=1)&&(x<=n))/n` will work even without the Statistics Toolbox, as long as **n** is a positive integer.	`((x==round(x)) && (x >= 1) && (x <= n))/n`
217	Compute probability that a random vector from the multinomial distribution with probability vector $\vec{p}$ has the value $\vec{x}$	`mnpdf(x,p)` Note: vector **p** must sum to one. Also, **x** and **p** can be vectors of length k, or if one or both are $m \times k$ matrices then the computations are performed for each row.	`dmultinom(x,prob=p)`

Note: one or more of the parameters in the above "*pdf" (MATLAB) or "d*" (R) functions can be vectors, but they must be the same size. Scalars are promoted to arrays of the appropriate size.

The corresponding CDF functions are below:

No.	Description	MATLAB	R
218	Compute probability that a random variable from the Binomial(n,p) distribution is less than or equal to **x** (i.e. the cumulative distribution function, or cdf).	`binocdf(x,n,p)`. Without the Statistics Toolbox, as long as **n** is a non-negative integer, this will work: `r = 0:floor(x); sum(factorial(n)./ (factorial(r).*factorial(n-r)) .*p.^r.*(1-p).^(n-r))`. (Unfortunately, MATLAB's **nchoosek** function won't take a vector argument for **k**.)	`pbinom(x,n,p)`
219	Compute probability that a random variable from the Poisson(λ) distribution is less than or equal to **x**.	`poisscdf(x,lambda)`. Without the Statistics Toolbox, as long as **lambda** $\geq$ 0, this will work: `r = 0:floor(x); sum(exp(-lambda)*lambda.^r ./factorial(r))`	`ppois(x,lambda)`
220	Compute cumulative distribution function at **x** for a random variable from the exponential distribution with mean μ.	`expcdf(x,mu)` or `(x>=0)*(1-exp(-x/mu))` will work even without the Statistics Toolbox, as long as **mu** is positive.	`pexp(x,1/mu)`
221	Compute cumulative distribution function at **x** for a random variable from the Normal distribution with mean μ and standard deviation σ.	`normcdf(x,mu,sigma)` or `1/2 - erf(-(x-mu)/(sigma*sqrt(2)))/2` will work even without the Statistics Toolbox, as long as **sigma** is positive.	`pnorm(x,mu,sigma)`
222	Compute cumulative distribution function at **x** for a random variable from the continuous uniform distribution on interval (a,b).	`unifcdf(x,a,b)` or `(x>a)*(min(x,b)-a)/(b-a)` will work even without the Statistics Toolbox, as long as **b** > **a**.	`punif(x,a,b)`
223	Compute probability that a random variable from the discrete uniform distribution on integers $1\ldots n$ is less than or equal to **x**.	`unidcdf(x,n)` or `(x>=1)*min(floor(x),n)/n` will work even without the Statistics Toolbox, as long as **n** is a positive integer.	`(x>=1)*min(floor(x),n)/n`

7 Graphics

7.1 Various types of plotting

No.	Description	MATLAB	R
224	Create a new figure window	`figure`	`dev.new()` Notes: internally, on Windows this calls `windows()`, on MacOS it calls `quartz()`, and on Linux it calls `x11()`. `x11()` is also available on MacOS. In R sometime after 2.7.0, X11 graphics started doing antialising by default, which makes plots look smoother but takes longer to draw. If you are using R on Linux (which uses X11 graphics by default) or X11 graphics on MacOS and notice that figure plotting is extremely slow (especially if making many plots), do this before calling **dev.new()**: `X11.options(type='Xlib')` or `X11.options(antialias='none')`. Or just use e.g. `x11(type='Xlib')` to make new figure windows. They are uglier (lines are more jagged), but render much more quickly.
225	Select figure number n	`figure(n)` (will create the figure if it doesn't exist)	`dev.set(n)` (returns the actual device selected; will be different from n if there is no figure device with number n)
226	Determine which figure window is currently active	`gcf`	`dev.cur()`
227	List open figure windows	`get(0,'children')` (The 0 handle refers to the root graphics object.)	`dev.list()`
228	Close figure window(s)	`close` to close the current figure window, `close(n)` to close a specified figure, and `close all` to close all figures	`dev.off()` to close the currently active figure device, `dev.off(n)` to close a specified one, and `graphics.off()` to close all figure devices.
229	Plot points using open circles	`plot(x,y,'o')`	`plot(x,y)`
230	Plot points using solid lines	`plot(x,y)`	`plot(x,y,type='l')` (Note: that's a lower-case 'L', not the number 1)
231	Plotting: color, point markers, linestyle	`plot(x,y,str)` where **str** is a string specifying color, point marker, and/or linestyle (see table below) (e.g. `'gs--'` for green squares with dashed line)	`plot(x,y,type=str1, pch=arg2,col=str3, lty=arg4)` See tables below for possible values of the 4 parameters
232	Plotting with logarithmic axes	`semilogx`, `semilogy`, and `loglog` functions take arguments like **plot**, and plot with logarithmic scales for x, y, and both axes, respectively	`plot(..., log='x')`, `plot(..., log='y')`, and `plot(..., log='xy')` plot with logarithmic scales for x, y, and both axes, respectively

No.	Description	MATLAB	R
233	Make bar graph where the x coordinates of the bars are in **x**, and their heights are in **y**	`bar(x,y)` Or just `bar(y)` if you only want to specify heights. Note: if A is a matrix, `bar(A)` interprets each column as a separate set of observations, and each row as a different observation within a set. So a 20×2 matrix is plotted as 2 sets of 20 observations, while a 2×20 matrix is plotted as 20 sets of 2 observations.	Can't do this in R; but `barplot(y)` makes a bar graph where you specify the heights, `barplot(y,w)` also specifies the widths of the bars, and `hist` can make plots like this too.
234	Make histogram of values in **x**	`hist(x)`	`hist(x)`
235	Given vector **x** containing integer values, make a bar graph where the x coordinates of bars are the values, and heights are the counts of how many times the values appear in **x**	`v=unique(x); c=hist(x,v); bar(v,c)`	`barplot(table(x))`
236	Given vector **x** containing continuous values, lump the data into k bins and make a histogram / bar graph of the binned data	`[c,m] = hist(x,k); bar(m,c)` or for slightly different plot style use `hist(x,k)`	`hist(x,seq(min(x), max(x), length.out=k+1))`
237	Make a plot containing errorbars of height **s** above and below (x, y) points	`errorbar(x,y,s)`	`errbar(x,y,y+s,y-s)` Note: **errbar** is part of the **Hmisc** package (see item 316 for how to install/load packages).
238	Make a plot containing errorbars of height **a** above and **b** below (x, y) points	`errorbar(x,y,b,a)`	`errbar(x,y,y+a,y-b)` Note: **errbar** is part of the **Hmisc** package (see item 316 for how to install/load packages).
239	Other types of 2-D plots	`stem(x,y)` and `stairs(x,y)` for other types of 2-D plots. `polar(theta,r)` to use polar coordinates for plotting.	`pie(v)`

No.	Description	MATLAB	R
240	Make a 3-D plot of some data points with given x, y, z coordinates in the vectors **x**, **y**, and **z**.	`plot3(x,y,z)` This works much like **plot**, as far as plotting symbols, line-types, and colors.	`cloud(z~x*y)` You can also use arguments **pch** and **col** as with `plot`. To make a 3-D plot with lines, do `cloud(z~x*y,type='l', panel.cloud=panel.3dwire)`
241	Surface plot of data in matrix **A**	`surf(A)` You can then click on the small curved arrow in the figure window (or choose "Rotate 3D" from the "Tools" menu), and then click and drag the mouse in the figure to rotate it in three dimensions.	`persp(A)` You can include shading in the image via e.g. `persp(A,shade=0.5)`. There are two viewing angles you can also specify, among other parameters, e.g. `persp(A, shade=0.5, theta=50, phi=35)`.

242	Surface plot of $f(x,y) = sin(x+y)\sqrt{y}$ for 100 values of x between 0 and 10, and 90 values of y between 2 and 8	`x = linspace(0,10,100);`
		`y = linspace(2,8,90);`
		`[X,Y] = meshgrid(x,y);`
		`Z = sin(X+Y).*sqrt(Y);`
		`surf(X,Y,Z)`
		`shading flat`
			`x = seq(0,10,len=100)`
			`y = seq(2,8,len=90)`
			`f = function(x,y)`
			`  return(sin(x+y)*sqrt(y))`
			`z = outer(x,y,f)`
			`persp(x,y,z)`

243	Other ways of plotting the data from the previous command	`mesh(X,Y,Z)`, `surfc(X,Y,Z)`, `surfl(X,Y,Z)`, `contour(X,Y,Z)`, `pcolor(X,Y,Z)`, `waterfall(X,Y,Z)`. Also see the `slice` command.	`contour(x,y,z)` Or do `s=expand.grid(x=x,y=y)`, and then `wireframe(z~x*y,s)` or `wireframe(z~x*y,s,shade=TRUE)` (Note: **wireframe** is part of the **lattice** package; see item 316 for how to load packages). If you have vectors **x**, **y**, and **z** all the same length, you can also do `symbols(x,y,z)`.
244	Set axis ranges in a figure window	`axis([x1 x2 y1 y2])`	You have to do this when you make the plot, e.g. `plot(x,y,xlim=c(x1,x2), ylim=c(y1,y2))`
245	Add title to plot	`title('somestring')`	`title(main='somestring')` adds a main title, `title(sub='somestring')` adds a subtitle. You can also include **main=** and **sub=** arguments in a **plot** command.
246	Add axis labels to plot	`xlabel('somestring')` and `ylabel('somestring')`	`title(xlab='somestring', ylab='anotherstr')`. You can also include **xlab=** and **ylab=** arguments in a **plot** command.

No.	Description	MATLAB	R
247	Include Greek letters or symbols in plot axis labels	You can use basic TeX commands, e.g. `plot(x,y); xlabel('\phi^2 + \mu_{i,j}')` or `xlabel('fecundity \phi')` See also **help tex** and parts of **doc text_props** for more about building labels using general LaTeX commands	`plot(x,y,xlab= expression(phi^2 + mu['i,j']))` or `plot(x,y,xlab=expression( paste('fecundity ', phi)))` See also **help(plotmath)** and p. 98 of the *R Graphics* book by Paul Murrell for more.
248	Change font size to 16 in plot labels	For the legends and numerical axis labels, use `set(gca, 'FontSize', 16)`, and for text labels on axes do e.g. `xlabel('my x var', 'FontSize', 16)`	For on-screen graphics, do `par(ps=16)` followed by e.g. a `plot` command. For PostScript or PDF plots, add a `pointsize=16` argument, e.g. `pdf('myfile.pdf', width=8, height=8, pointsize=16)` (see items 264 and 265)
249	Add grid lines to plot	`grid on` (and `grid off` to turn off)	`grid()` Note that if you'll be printing the plot, the default style for grid-lines is to use gray dotted lines, which are almost invisible on some printers. You may want to do e.g. `grid(lty='dashed', col='black')` to use black dashed lines which are easier to see.
250	Add a text label to a plot	`text(x,y,'hello')`	`text(x,y,'hello')`
251	Add set of text labels to a plot. **xv** and **yv** are vectors.	`s={'hi', 'there'}; text(xv,yv,s)`	`s=c('hi', 'there'); text(xv,yv,s)`
252	Add an arrow to current plot, with tail at (xt, yt) and head at (xh, yh)	`annotation('arrow', [xt xh], [yt yh])` Note: coordinates should be normalized figure coordinates, not coordinates within your displayed axes. Find and download from The Mathworks the file **dsxy2figxy.m** which converts for you, then do this: `[fx,fy]=dsxy2figxy([xt xh], [yt yh]); annotation('arrow', fx, fy)`	`arrows(xt, yt, xh, yh)`
253	Add a double-headed arrow to current plot, with coordinates $(x0, y0)$ and $(x1, y1)$	`annotation('doublearrow', [x0 x1], [y0 y1])` See note in previous item about normalized figure coordinates.	`arrows(x0, y0, x1, y1, code=3)`
254	Add figure legend to top-left corner of plot	`legend('first', 'second', 'Location', 'NorthWest')`	`legend('topleft', legend=c('first', 'second'), col=c('red', 'blue'), pch=c('*','o'))`

MATLAB note: sometimes you build a graph piece-by-piece, and then want to manually add a legend which doesn't correspond with the order you put things in the plot. You can manually construct a legend by plotting "invisible" things, then building the legend using them. E.g. to make a legend with black stars and solid lines, and red circles and dashed lines: `h1=plot(0,0,'k*-'); set(h1,'Visible', 'off'); h2=plot(0,0,'k*-'); set(h2,'Visible', 'off'); legend([h1 h2], 'blah, 'whoa')`. Just be sure to choose coordinates for your "invisible" points within the current figure's axis ranges.

No.	Description	MATLAB	R
255	Adding more things to a figure	`hold on` means everything plotted from now on in that figure window is added to what's already there. `hold off` turns it off. `clf` clears the figure and turns off hold.	`points(...)` and `lines(...)` work like **plot**, but add to what's already in the figure rather than clearing the figure first. **points** and **lines** are basically identical, just with different default plotting styles. Note: axes are not recalculated/redrawn when adding more things to a figure.
256	Plot multiple data sets at once	`plot(x,y)` where **x** and **y** are 2-D matrices. Each column of **x** is plotted against the corresponding column of **y**. If **x** has only one column, it will be re-used.	`matplot(x,y)` where **x** and **y** are 2-D matrices. Each column of **x** is plotted against the corresponding column of **y**. If **x** has only one column, it will be re-used.
257	Plot $\sin(2x)$ for x between 7 and 18	`fplot('sin(2*x)', [7 18])`	`curve(sin(2*x), 7, 18, 200)` makes the plot, by sampling the value of the function at 200 values between 7 and 18 (if you don't specify the number of points, 101 is the default). You could do this manually yourself via commands like `tmpx=seq(7,18,len=200); plot(tmpx, sin(2*tmpx))`.
258	Plot color image of integer values in matrix **A**	`image(A)` to use array values as raw indices into colormap, or `imagesc(A)` to automatically scale values first (these both draw row 1 of the matrix at the top of the image); or `pcolor(A)` (draws row 1 of the matrix at the bottom of the image). After using `pcolor`, try the commands `shading flat` or `shading interp`.	`image(A)` (it rotates the matrix 90 degrees counterclockwise: it draws row 1 of A as the left column of the image, and column 1 of A as the bottom row of the image, so the row number is the x coord and column number is the y coord). It also rescales colors. If you are using a colormap with k entries, but the value k does not appear in A, use `image(A,zlim=c(1,k))` to avoid rescaling of colors. Or e.g. `image(A,zlim=c(0,k-1))` if you want values 0 through $k-1$ to be plotted using the k colors.
259	Add colorbar legend to image plot	`colorbar`, after using `image` or `pcolor`.	Use `filled.contour(A)` rather than `image(A)`, although it "blurs" the data via interpolation, or use `levelplot(A)` from the **lattice** package (see item 316 for how to load packages). To use a colormap with the latter, do e.g. `levelplot(A,col.regions= terrain.colors(100))`.
260	Set colormap in image	`colormap(hot)`. Instead of `hot`, you can also use `gray`, `flag`, `jet` (the default), `cool`, `bone`, `copper`, `pink`, `hsv`, `prism`. By default, the length of the new colormap is the same as the currently-installed one; use e.g. `colormap(hot(256))` to specify the number of entries.	`image(A,col=terrain.colors(100))`. The parameter 100 specifies the length of the colormap. Other colormaps are `heat.colors()`, `topo.colors()`, and `cm.colors()`.

No.	Description	MATLAB	R
261	Build your own colormap using Red/Green/Blue triplets	Use an $n \times 3$ matrix; each row gives R,G,B intensities between 0 and 1. Can use as argument with **colormap**. E.g. for 2 colors: `mycmap = [0.5 0.8 0.2 ; 0.2 0.2 0.7]`	Use a vector of hexadecimal strings, each beginning with '#' and giving R,G,B intensities between 00 and FF. E.g. `c('#80CC33','#3333B3')`; can use as argument to **col=** parameter to `image`. You can build such a vector of strings from vectors of Red, Green, and Blue intensities (each between 0 and 1) as follows (for a 2-color example): `r=c(0.5,0.2); g=c(0.8,0.2); b=c(0.2,0.7); mycolors=rgb(r,g,b)`.

MATLAB plotting specifications, for use with `plot`, `fplot`, `semilogx`, `semilogy`, `loglog`, etc:

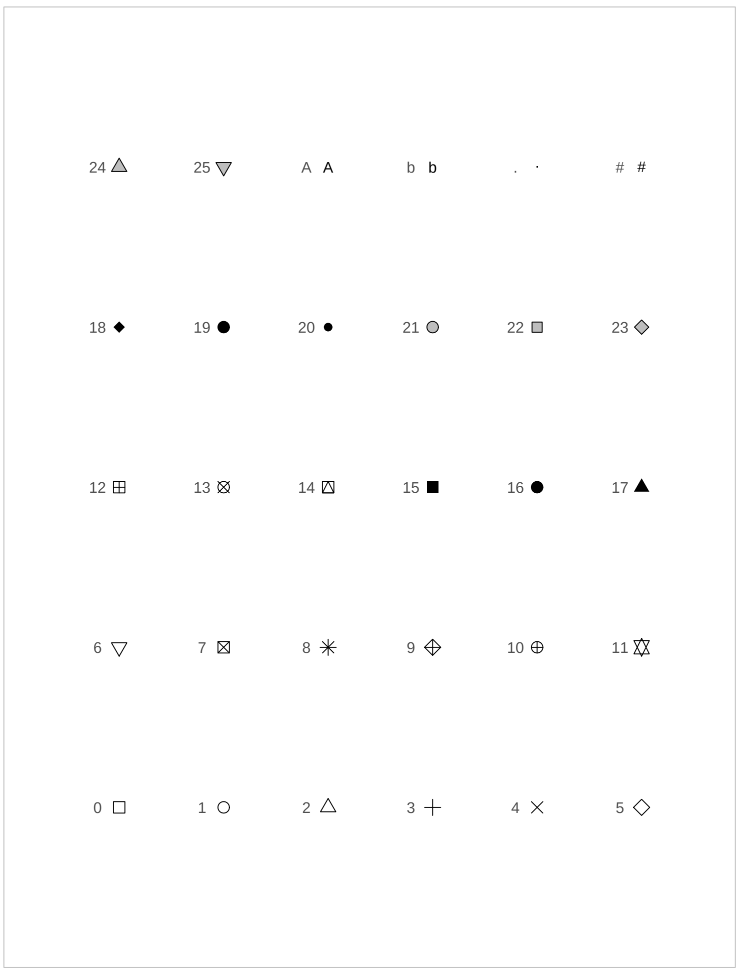
Symbol	Color	Symbol	Marker	Symbol	Linestyle
`b`	blue	`.`	point (.)	`-`	solid line
`g`	green	`o`	circle (○)	`:`	dotted line
`r`	red	`x`	cross (×)	`-.`	dash-dot line
`c`	cyan	`+`	plus sign (+)	`--`	dashed line
`m`	magenta	`*`	asterisk (∗)		
`y`	yellow	`s`	square (□)		
`k`	black	`d`	diamond (◊)		
`w`	white	`v`	triangle (down) (▽)		
		`^`	triangle (up) (△)		
		`<`	triangle (left) (◁)		
		`>`	triangle (right) (▷)		
		`p`	pentragram star		
		`h`	hexagram star		

R plotting specifications for **col** (color), **pch** (plotting character), and **type** arguments, for use with `plot`, `matplot`, `points`, and `lines`:

`col`	Description	`pch`	Description	`type`	Description
`'blue'`	Blue	`'a'`	a (similarly for other characters, but see '.' below for an exception	`p`	points
`'green'`	Green	19	solid circle	`l`	lines
`'red'`	Red	20	bullet (smaller circle)	`b`	both
`'cyan'`	Cyan	21	open circle	`c`	lines part only of "b"
`'magenta'`	Magenta	22	square	`o`	lines, points overplotted
`'yellow'`	Yellow	23	diamond	`h`	histogram-like lines
`'black'`	Black	24	triangle point-up	`s`	steps
`'#RRGGBB'`	hexadecimal specification of Red, Green, Blue	25	triangle point-down	`S`	another kind of steps
(Other names)	See `colors()` for list of available color names.	`'.'`	rectangle of size 0.01 inch, 1 pixel, or 1 point (1/72 inch) depending on device	`n`	no plotting
			(See table on next page for more)		

R plotting specifications for **lty** (line-type) argument, for use with `plot`, `matplot`, `points`, and `lines`:

`lty`	Description
0	blank
1	solid
2	dashed
3	dotted
4	dotdash
5	longdash
6	twodash



R plotting characters, i.e. values for **pch** argument (from the book *R Graphics*, by Paul Murrell, Chapman & Hall / CRC, 2006)

No.	Description	MATLAB	R
262	Divide up a figure window into smaller sub-figures	`subplot(m,n,k)` divides the current figure window into an $m \times n$ array of subplots, and draws in subplot number k as numbered in "reading order," i.e. left-to-right, top-to-bottom. E.g. `subplot(2,3,4)` selects the first sub-figure in the second row of a 2×3 array of sub-figures. You can do more complex things, e.g. `subplot(5,5,[1 2 6 7])` selects the first two subplots in the first row, and first two subplots in the second row, i.e. gives you a bigger subplot within a 5×5 array of subplots. (If you that command followed by e.g. `subplot(5,5,3)` you'll see what's meant by that.)	There are several ways to do this, e.g. using `layout` or `split.screen`, although they aren't quite as friendly as MATLAB 's. E.g. if you let $A = \begin{bmatrix} 1 & 1 & 2 \\ 1 & 1 & 3 \\ 4 & 5 & 6 \end{bmatrix}$, then `layout(A)` will divide the figure into 6 sub-figures: you can imagine the figure divide into a 3×3 matrix of smaller blocks; sub-figure 1 will take up the upper-left 2×2 portion, and sub-figures 2–6 will take up smaller portions, according to the positions of those numbers in the matrix A. Consecutive plotting commands will draw into successive sub-figures; there doesn't seem to be a way to explicitly specify which sub-figure to draw into next. To use `split.screen`, you can do e.g. `split.screen(c(2,1))` to split into a 2×1 matrix of sub-figures (numbered 1 and 2). Then `split.screen(c(1,3),2)` splits sub-figure 2 into a 1×3 matrix of smaller sub-figures (numbered 3, 4, and 5). `screen(4)` will then select sub-figure number 4, and subsequent plotting commands will draw into it. A third way to accomplish this is via the commands `par(mfrow=)` or `par(mfcol=)` to split the figure window, and `par(mfg=)` to select which sub-figure to draw into. Note that the above methods are all incompatible with each other.
263	Force graphics windows to update	`drawnow` (MATLAB normally only updates figure windows when a script/function finishes and returns control to the MATLAB prompt, or under a couple of other circumstances. This forces it to update figure windows to reflect any recent plotting commands.)	R automatically updates graphics windows even before functions/scripts finish executing, so it's not necessary to explictly request it. But note that some graphics functions (particularly those in the **lattice** package) don't display their results when called from scripts or functions; e.g. rather than `levelplot(...)` you need to do `print(levelplot(...))`. Such functions will automatically display their plots when called interactively from the command prompt.

7.2 Printing/saving graphics

No.	Description	MATLAB	R
264	To print/save to a PDF file named **fname.pdf**	`print -dpdf fname` saves the contents of currently active figure window	First do `pdf('fname.pdf')`. Then, do various plotting commands to make your image, as if you were plotting in a window. Finally, do `dev.off()` to close/save the PDF file. To print the contents of the active figure window, do `dev.copy(device=pdf, file='fname.pdf'); dev.off()`. (But this will not work if you've turned off the display list via `dev.control(displaylist= 'inhibit')`.)
265	To print/save to a PostScript file **fname.ps** or **fname.eps**	`print -dps fname` for black & white PostScript; `print -dpsc fname` for color PostScript; `print -deps fname` for black & white Encapsulated PostScript; `print -depsc fname` for color Encapsulated PostScript. The first two save to **fname.ps**, while the latter two save to **fname.eps**.	`postscript('fname.eps')`, followed by your plotting commands, followed by `dev.off()` to close/save the file. Note: you may want to use `postscript('fname.eps', horizontal=FALSE)` to save your figure in portrait mode rather than the default landscape mode. To print the contents of the active figure window, do `dev.copy(device=postscript, file='fname.eps'); dev.off()`. (But this will not work if you've turned off the display list via `dev.control(displaylist= 'inhibit')`.) You can also include the `horizontal=FALSE` argument with `dev.copy()`.
266	To print/save to a JPEG file **fname.jpg** with jpeg quality = 90 (higher quality looks better but makes the file larger)	`print -djpeg90 fname`	`jpeg('fname.jpg',quality=90)`, followed by your plotting commands, followed by `dev.off()` to close/save the file.

7.3 Animating cellular automata / lattice simulations

No.	Description	MATLAB	R
267	To display images of cellular automata or other lattice simulations while running in real time	Repeatedly use either `pcolor` or `image` to display the data. Don't forget to call `drawnow` as well, otherwise the figure window will not be updated with each image.	If you simply call `image` repeatedly, there is a great deal of flickering/flashing. To avoid this, after drawing the image for the first time using e.g. `image(A)`, from then on only use `image(A,add=TRUE)`, which avoids redrawing the entire image (and the associated flicker). However, this will soon consume a great deal of memory, as all drawn images are saved in the image buffer. There are two solutions to that problem: (1) every k time steps, leave off the "`add=TRUE`" argument to flush the image buffer (and get occasional flickering), where you choose k to balance the flickering vs. memory-usage tradeoff; or (2) after drawing the first image, do `dev.control(displaylist='inhibit')` to prohibit retaining the data. However, the latter solution means that after the simulation is done, the figure window will not be redrawn if it is resized, or temporarily obscured by another window. (A call to `dev.control(displaylist='enable')` and then one final `image(A)` at the end of the simulation will re-enable re-drawing after resizing or obscuring, without consuming extra memory.)

8 Working with files

No.	Description	MATLAB	R
268	Create a folder (also known as a "directory")	`mkdir dirname`	`dir.create('dirname')`
269	Set/change working directory	`cd dirname`	`setwd('dirname')`
270	See list of files in current working directory	`dir`	`dir()`
271	Run commands in file 'foo.m' or 'foo.R' respectively	`foo`	`source('foo.R')`
272	Read data from text file "data.txt" into matrix A	`A=load('data.txt')` or `A=importdata('data.txt')` Note that both routines will ignore comments (anything on a line following a "%" character)	`A=as.matrix(read.table( 'data.txt'))` This will ignore comments (anything on a line following a "`#`" character). To ignore comments indicated by "%", do `A=as.matrix(read.table( 'data.txt', comment.char='%'))`
273	Write data from matrix A into text file "data.txt"	`save data.txt A -ascii`	`write(A, file='data.txt', ncolumn=dim(A)[2])`

9 Miscellaneous

9.1 Variables

No.	Description	MATLAB	R
274	Assigning to variables	`x = 5`	`x <- 5` or `x = 5` Note: for compatibility with S-plus, many people prefer the first form.
275	From within a function, assign a value to variable **y** in the base environment (i.e. the command prompt environment)	`assignin('base', 'y', 7)`	`y <<- 7`
276	From within a function, access the value of variable **y** in the base environment (i.e. the command prompt environment)	`evalin('base', 'y')`	`get('y', envir=globalenv())` Though note that inside a function, if there isn't a local variable **y**, then just the expression `y` will look for one in the base environment, but if there is a local **y** then that one will be used instead.
277	Short list of defined variables	`who`	`ls()`
278	Long list of defined variables	`whos`	`ls.str()`
279	See detailed info about the variable **ab**	`whos ab`	`str(ab)`
280	See detailed info about all variables with "ab" in their name	`whos *ab*`	`ls.str(pattern='ab')`
281	Open graphical data editor, to edit the value of variable **A** (useful for editing values in a matrix, though it works for non-matrix variables as well)	`openvar(A)`, or double-click on the variable in the Workspace pane (if it's being displayed) of your MATLABdesktop	`fix(A)`
282	Clear one variable	`clear x`	`rm(x)`
283	Clear two variables	`clear x y`	`rm(x,y)`
284	Clear all variables	`clear all`	`rm(list=ls())`
285	See what type of object **x** is	`class(x)`	`class(x)`
286	(Variable names)	Variable names must begin with a letter, but after that they may contain any combination of letters, digits, and the underscore character. Names are case-sensitive.	Variable names may contain letters, digits, the period, and the underscore character. They cannot begin with a digit or underscore, or with a period followed by a digit. Names are case-sensitive.
287	Result of last command	`ans` contains the result of the last command which did not assign its value to a variable. E.g. after `2+5; x=3`, then **ans** will contain 7.	`.Last.value` contains the result of the last command, whether or not its value was assigned to a variable. E.g. after `2+5; x=3`, then **.Last.value** will contain 3.

9.2 Strings and Misc.

No.	Description	MATLAB	R

288	Line continuation	If you want to break up a MATLAB command over more than one line, end all but the last line with three periods: "...". E.g.:
		`x = 3 + ...`
		`    4`
		or
		`x = 3 ...`
		`   + 4`
			In R, you can spread commands out over multiple lines, and nothing extra is necessary. R will continue reading input until the command is complete. However, this only works when the syntax makes it clear that the first line was not complete. E.g.:
			`x = 3 +`
			`   4`
			works, but
			`x = 3`
			`   + 4`
			does not treat the second line as a continuation of the first.

289	Controlling formatting of output	`format short g` and `format long g` are handy; see `help format`	`options(digits=6)` tells R you'd like to use 6 digits of precision in values it displays (it is only a suggestion, not strictly followed)
290	Exit the program	`quit` or `exit`	`q()` or `quit()`
291	Comments	`% this is a comment`	`# this is a comment`
292	Display a string	`disp('hi there')` or to omit trailing newline use `fprintf('hi there')`	`print('hi there')`
293	Display a string containing single quotes	`disp('It''s nice')` or to omit trailing newline `fprintf('It''s nice')`	`print('It\'s nice')` or `print("It's nice")`
294	Give prompt and read numerical input from user	`x = input('Enter data:')`	`print('Enter data:'); x=scan()` But note: if in a script and you use the Edit → Execute menu item to run it, the selected text after the **scan** statement will be used as source for the input, rather than keyboard.
295	Give prompt and read character (string) input from user	`x = input('Enter string:','s')`	`x = readline('Enter string:')`
296	Concatenate strings	`['two hal' 'ves']`	`paste('two hal', 'ves', sep='')`
297	Concatenate strings stored in a vector	`v={'two ', 'halves'};` `strcat(v{:})` But note that this drops trailing spaces on strings. To avoid that, instead do `strcat([v{:}])`	`v=c('two ', 'halves');` `paste(v, collapse='')`
298	Extract substring of a string	`text1='hi there';` `text2=text(2:6)`	`text1='hi there';` `text2=substr(text1,2,6)`
299	Determine whether elements of a vector are in a set, and give positions of corresponding elements in the set.	`x = {'a', 'aa', 'bc', 'c'}; y = {'da', 'a', 'bc', 'a', 'bc', 'aa'}; [tf, loc]=ismember(x,y)` Then **loc** contains the locations of *last* occurrences of elements of **x** in the set **y**, and 0 for unmatched elements.	`x = c('a', 'aa', 'bc', 'c'); y = c('da', 'a', 'bc', 'a', 'bc', 'aa'); loc=match(x,y)` Then **loc** contains the locations of *first* occurences of elements of **x** in the set **y**, and NA for unmatched elements.

No.	Description	MATLAB	R
300	Convert number to string	`num2str(x)`	`as.character(x)`

301	Use **sprintf** to create a formatted string. Use **%d** for integers ("d" stands for "decimal", i.e. base 10), **%f** for floating-point numbers, **%e** for scientific-notation floating point, **%g** to automatically choose **%e** or **%f** based on the value. You can specify field-widths/precisions, e.g. **%5d** for integers with padding to 5 spaces, or **%.7f** for floating-point with 7 digits of precision. There are many other options too; see the docs.	`x=2; y=3.5;`
		`s=sprintf('x is %d, y=%g', ...`
		`  x, y)`
			`x=2; y=3.5`
			`s=sprintf('x is %d, y is %g',`
			`  x, y)`

302	Machine epsilon ϵ_{mach}, i.e. difference between 1 and the next largest double-precision floating-point number	`eps` (See **help eps** for various other things **eps** can give.)	`.Machine$double.eps`
303	Pause for x seconds	`pause(x)`	`Sys.sleep(x)`
304	Wait for user to press any key	`pause`	Don't know of a way to do this in R, but `scan(quiet=TRUE)` will wait until the user presses the Enter key
305	Measure CPU time used to do some commands	`t1=cputime; ...commands... ; cputime-t1`	`t1=proc.time(); ...commands... ; (proc.time()-t1)[1]`
306	Measure elapsed ("wall-clock") time used to do some commands	`tic; ...commands... ; toc` or `t1=clock; ...commands... ; etime(clock,t1)`	`t1=proc.time(); ...commands... ; (proc.time()-t1)[3]`
307	Print an error message an interrupt execution	`error('Problem!')`	`stop('Problem!')`
308	Print a warning message	`warning('Smaller problem!')`	`warning('Smaller problem!')`
309	Putting multiple statements on one line	Separate statements by commas or semicolons. A semicolon at the end of a statement suppresses display of the results (also useful even with just a single statement on a line), while a comma does not.	Separate statements by semicolons.
310	Evaluate contents of a string **s** as command(s).	`eval(s)`	`eval(parse(text=s))`
311	Get a command prompt for debugging, while executing a script or function. While at that prompt, you can type expressions to see the values of variables, etc.	Insert the command `keyboard` in your file. Note that your prompt will change to **K>>**. When you are done debugging and want to continue executing the file, type `return`.	Insert the command `browser()` in your file. Note that your prompt will change to **Browse[1]>**. When you are done debugging and want to continue executing the file, either type `c` or just press return (i.e. enter a blank line). Note, if you type `n`, you enter the step debugger.

No.	Description	MATLAB	R
312	Show where a command is	`which sqrt` shows you where the file defining the **sqrt** function is (but note that many basic functions are "built in," so the MATLAB function file is really just a stub containing documentation). This is useful if a command is doing something strange, e.g. **sqrt** isn't working. If you've accidentally defined a *variable* called **sqrt**, then `which sqrt` will tell you, so you can `clear sqrt` to erase it so that you can go back to using the *function* **sqrt**.	R does not execute commands directly from files, so there is no equivalent command.
313	Query/set the search path.	`path` displays the current search path (the list of places MATLAB searches for commands you enter). To add a directory `~/foo` to the beginning of the search path, do `addpath ~/foo -begin` or to add it to the end of the path, do `addpath ~/foo -end` (Note: you should generally add the full path of a directory, i.e. in Linux or Mac OS-X something like **~/foo** as above or of the form **/usr/local/lib/foo**, while under Windows it would be something like **C:/foo**)	R does not use a search path to look for files.
314	Startup sequence	If a file **startup.m** exists in the startup directory for MATLAB, its contents are executed. (See the MATLAB docs for how to change the startup directory.)	If a file **.Rprofile** exists in the current directory or the user's home directory (in that order), its contents are sourced; saved data from the file **.RData** (if it exists) are then loaded. If a function **.First()** has been defined, it is then called (so the obvious place to define this function is in your **.Rprofile** file).
315	Shutdown sequence	Upon typing `quit` or `exit`, MATLAB will run the script **finish.m** if present somewhere in the search path.	Upon typing `q()` or `quit()`, R will call the function **.Last()** if it has been defined (one obvious place to define it would be in the **.Rprofile** file)

No.	Description	MATLAB	R
316	Install and load a package.	MATLAB does not have packages. It has toolboxes, which you can purchase and install. "Contributed" code (written by end users) can simply be downloaded and put in a directory which you then add to MATLAB's path (see item 313 for how to add things to MATLAB's path).	To install e.g. the **deSolve** package, you can use the command `install.packages('deSolve')`. You then need to load the package in order to use it, via the command `library('deSolve')`. When running R again later you'll need to load the package again to use it, but you should not need to re-install it. Note that the **lattice** package is typically included with binary distributions of R, so it only needs to be loaded, not installed.

10 Spatial Modeling

No.	Description	MATLAB	R
317	Take an $L \times$L matrix **A** of 0s and 1s, and "seed" fraction p of the 0s (turn them into 1s), not changing entries which are already 1.	`A = (A | (rand(L) < p))*1;`	`A = (A | (matrix(runif(L^2),L) < p))*1`
318	Take an $L \times L$ matrix **A** of 0s and 1s, and "kill" fraction p of the 1s (turn them into 0s), not changing the rest of the entries	`A = (A & (rand(L) < 1-p))*1;`	`A = (A & (matrix(runif(L^2),L) < 1-p))*1`
319	Do "wraparound" on a coordinate **newx** that you've already calculated. You can replace **newx** with **x+dx** if you want to do wraparound on an offset x coordinate.	`mod(newx-1,L)+1` Note: for portability with other languages such as C which handle MOD of negative values differently, you may want to get in the habit of instead doing `mod(newx-1+L,L)+1`	`((newx-1) %% L) + 1` Note: for portability with other languages such as C which handle MOD of negative values differently, you may want to get in the habit of instead doing `((newx-1+L)%%L) + 1`

320	Randomly initialize a portion of an array: set fraction p of sites in rows **iy1** through **iy2** and columns **ix1** through **ix2** equal to 1 (and set the rest of the sites in that block equal to zero). Note: this assume **iy1 < iy2** and **ix1 < ix2**.	`dx=ix2-ix1+1; dy=iy2-iy1+1;`
		`A(iy1:iy2,ix1:ix2) = ...`
		`(rand(dy,dx) < p0)*1;`
			`dx=ix2-ix1+1; dy=iy2-iy1+1;`
			`A[iy1:iy2,ix1:ix2] =`
			`(matrix(runif(dy*dx),dy) <`
			`p0)*1`

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Index of R commands and concepts