MATLAB ® / R Reference

June 24, 2014

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I wrote the first version of this reference during Spring 2007, as I learned R while teaching my Modeling & Simulation course 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. Earlier versions of the course had used MATLAB. In Spring 2007, some biology graduate students in the class asked if they could use R; 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 along, I started building this reference for my own use. In the end, I was pleasantly surprised that most things I do in MATLAB have fairly direct equivalents in R. I was also inspired to write this after seeing the "R for Octave Users" reference written by Robin Hankin, and have continued to add to the document.

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 are 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, and where possible I've avoided the use of MATLAB toolboxes or R packages which are not part of the core distributions. But if you believe you have a "better" way (either simpler, or more computationally efficient) to do something, feel free to let me know.

For those transitioning from MATLAB to R, you should check out the **pracma** package for R ("Practical Numerical Math Routines") — it has more than 200 functions which emulate MATLAB functions, which you may find very handy.

Acknowledgements: Thanks to Juan David Ospina Arango, Berry Boessenkool, Robert Bryce, Thomas Clerc, Alan Cobo-Lewis, Richard Cotton, Stephen Eglen, Andreas Handel, Niels Richard Hansen, Luke Hartigan, Roger Jeurissen, David Khabie-Zeitoune, Seungyeon Kim, Michael Kiparsky, Isaac Michaud, Andy Moody, Ben Morin, Lee Pang, Manas A. Pathak, Rachel Rier, Rune Schjellerup Philosof, Rachel Rier, William Simpson, David Winsemius, Corey Yanofsky, and Jian Ye for corrections and contributions.

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	Given $r\times c$ matrix A, build an $rm \times cn$ matrix by sticking m copies of A horizontally and n copies vertically	`repmat(A,m,n)`	`kronecker(matrix(1,m,n),A)` or `matrix(1,m,n) %x% A`

27	Given vectors **x** and **y** of lengths m and n respectively, build $n\times m$ matrices **X** whose rows are copies of **x** and **Y** whose columns are copies of **y**	`[X,Y]=meshgrid(x,y)`	Use the **meshgrid** function from the **pracma** package as follows: `tmp=meshgrid(x,y); X=tmp$X; Y=tmp$Y` Or do the following:
			`m=length(x); n=length(y);`
			`X=matrix(rep(x,each=n),nrow=n);`
			`Y=matrix(rep(y,m),nrow=n)`

28	Given vectors **x** and **y** of lengths m and n respectively, build $n\times m$ matrices **A** where element $a_{ij} = e^{-x_i}\sin(3y_j)$	`bsxfun(@(x,y) exp(-x).*sin(3*y), x, y)'` Note that **x** must be a row vector and **y** must be a column vector; use **x(:)'** and **y(:)** to ensure this if necessary	`outer(exp(-x), sin(3*y))`
29	Reverse the order of elements in vector **v**	`v(end:-1:1)`	`rev(v)`

No.	Description	MATLAB	R
30	Column 2 of matrix **A**	`A(:,2)`	`A[,2]` Note: that gives the result as a vector. To make the result a $m\times1$ matrix instead, do `A[,2,drop=FALSE]`
31	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]`
32	All elements of **A** as a vector, column-by-column	`A(:)` (gives a column vector)	`c(A)`
33	Rows 2–4, columns 6–10 of **A** (this is a 3×5 matrix)	`A(2:4,6:10)`	`A[2:4,6:10]`
34	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)]`
35	Circularly shift the rows of matrix A down by s_1 elements, and right by s_2 elements	`circshift(A, [s1 s2])`	`circshift(A, c(s1,s2))` where **circshift** is in the **pracma** package. Or modulo arithmetic on indices will work: `m=dim(A)[1]; n=dim(A)[2]; A[(1:m-s1-1)%%m+1, (1:n-s2-1)%%n+1]`
36	Flip the order of elements in each row of matrix A	`fliplr(A)`	`fliplr(A)` using **fliplr** from the **pracma** package, or `t(apply(A,1,rev))` or `A[,ncol(A):1]`
37	Flip the order of elements in each column of matrix A	`flipud(A)`	`flipud(A)` using **flipud** from the **pracma** package, or `apply(A,2,rev)` or `A[nrow(A):1,]`

38	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)`	`arrayInd(ind, c(m,n))` or
			`r = ((ind-1) %% m) + 1`
			`c = floor((ind-1) / m) + 1`
			or `r=row(A)[ind]; c=col(A)[ind]`

39	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`
40	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`
41	Truncate vector **v**, keeping only the first 10 elements	`v = v(1:10)`	`v = v[1:10]`, or `length(v) = 10` also works

No.	Description	MATLAB	R
42	Extract elements of vector **v** from position **a** to the end	`v(a:end)`	`v[a:length(v)]`
43	All but the k^{th} element of vector **v**	`v([1:(k-1) (k+1):end])` or `v([k]) = [ ]` (but this will modify the original vector **v**)	`v[-k]`
44	All but the j^{th} and k^{th} elements of vector **v**	`v(~ismember(1:length(v),[j k]))` or `v([j k]) = [ ]` (but this will modify the original vector **v**)	`v[c(-j,-k)]`
45	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)`
46	Extract the lower-triangular portion of matrix A	`L = tril(A)`	`L = A; L[upper.tri(L)]=0`
47	Extract the upper-triangular portion of matrix A	`U = triu(A)`	`U = A; U[lower.tri(U)]=0`
48	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 348 for how to install/load packages).
49	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

50	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)`

51	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**.
52	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

53	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
54	$a+b$, $a-b$, ab, a/b	`a+b`, `a-b`, `a*b`, `a/b`	`a+b`, `a-b`, `a*b`, `a/b`
55	$\sqrt{a}$	`sqrt(a)`	`sqrt(a)`
56	a^b	`a^b`	`a^b`
57	$\|a\|$ (note: for complex arguments, this computes the modulus)	`abs(a)`	`abs(a)`
58	e^a	`exp(a)`	`exp(a)`
59	$\ln(a)$	`log(a)`	`log(a)`
60	$\log_2(a)$, $\log_{10}(a)$	`log2(a)`, `log10(a)`	`log2(a)`, `log10(a)`
61	$\sin(a)$, $\cos(a)$, $\tan(a)$	`sin(a)`, `cos(a)`, `tan(a)`	`sin(a)`, `cos(a)`, `tan(a)`
62	$\sin^{-1}(a)$, $\cos^{-1}(a)$, $\tan^{-1}(a)$	`asin(a)`, `acos(a)`, `atan(a)`	`asin(a)`, `acos(a)`, `atan(a)`
63	$\sinh(a)$, $\cosh(a)$, $\tanh(a)$	`sinh(a)`, `cosh(a)`, `tanh(a)`	`sinh(a)`, `cosh(a)`, `tanh(a)`
64	$\sinh^{-1}(a)$, $\cosh^{-1}(a)$, $\tanh^{-1}(a)$	`asinh(a)`, `acosh(a)`, `atanh(a)`	`asinh(a)`, `acosh(a)`, `atanh(a)`
65	n MOD k (modulo arithmetic)	`mod(n,k)`	`n %% k`
66	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.)
67	Round down to next lowest integer	`floor(x)`	`floor(x)`
68	Round up to next largest integer	`ceil(x)`	`ceiling(x)`
69	Round toward zero	`fix(x)`	`trunc(x)`
70	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)
71	Error function $\text{erf}(x) = (2/\sqrt{\pi})\int_0^x e^{-t^2}dt$	`erf(x)`	`2*pnorm(x*sqrt(2))-1`
72	Complementary error function $\text{cerf}(x) = (2/\sqrt{\pi})\int_x^\infty e^{-t^2}dt$ = 1-erf(x)	`erfc(x)`	`2*pnorm(x*sqrt(2),lower=FALSE)`
73	Inverse error function	`erfinv(x)`	`qnorm((1+x)/2)/sqrt(2)`
74	Inverse complementary error function	`erfcinv(x)`	`qnorm(x/2,lower=FALSE)/sqrt(2)`
75	Binomial coefficient $\binom{n}{k} = n!/(n!(n-k)!)$	`nchoosek(n,k)`	`choose(n,k)`
76	Bitwise logical operations (NOT, AND, OR, XOR, bit-shifting)	`bitcmp`, `bitand`, `bitor`, `bitxor`, `bitshift`	`bitwNot`, `bitwAnd`, `bitwOr`, `bitwXor`, `bitwShiftL`, `bitwShiftR`

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
77	Enter a complex number	`1+2i`	`1+2i`
78	Modulus (magnitude)	`abs(z)`	`abs(z)` or `Mod(z)`
79	Argument (angle)	`angle(z)`	`Arg(z)`
80	Complex conjugate	`conj(z)`	`Conj(z)`
81	Real part of z	`real(z)`	`Re(z)`
82	Imaginary part of z	`imag(z)`	`Im(z)`

3.3 Matrix/vector computations

No.	Description	MATLAB	R
83	Vector dot product $\vec{x} \cdot \vec{y} = \vec{x}^T\vec{y}$	`dot(x,y)`	`sum(x*y)`
84	Vector cross product $\vec{x} \times \vec{y}$	`cross(x,y)`	Not in base R, but you can use `cross(x,y)` after loading the **pracma** package (see item 348 for how to install/load packages)
85	Matrix multiplication AB	`A * B`	`A %*% B`
86	Element-by-element multiplication of A and B	`A .* B`	`A * B`
87	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
88	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.
89	Reduced echelon form of A	`rref(A)`	R does not have a function to do this
90	Determinant of **A**	`det(A)`	`det(A)`
91	Inverse of **A**	`inv(A)`	`solve(A)`
92	Trace of **A**	`trace(A)`	`sum(diag(A))`
93	AB^{-1}	`A/B`	`A %*% solve(B)`
94	Element-by-element division of A and B	`A ./ B`	`A / B`
95	$A^{-1}B$	`A\B`	`solve(A,B)`
96	Square the matrix A	`A^2`	`A %*% A`
97	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...`)
98	Raise each element of A to the k^{th} power	`A.^k`	`A^k`
99	Rank of matrix A	`rank(A)`	`qr(A)$rank`
100	Set **w** to be a vector of eigenvalues of **A**, and **V** a matrix containing the corresponding eigenvectors	`[V,D]=eig(A)` and then `w=diag(D)` since MATLAB returns the eigenvalues on the diagonal of **D**	`tmp=eigen(A); w=tmp$values; V=tmp$vectors`

No.	Description	MATLAB	R
101	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 348 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.
102	Singular-value decomposition: given $m \times n$ matrix A with $k = \min(m, n)$, find $m \times k$ matrix P with orthonormal columns, diagonal $k \times k$ matrix S, and $n \times k$ matrix Q with orthonormal columns so that $PSQ^T = A$	`[P,S,Q]=svd(A,'econ')`	`tmp=svd(A); P=tmp$u; Q=tmp$v;` `S=diag(tmp$d)`
103	Schur decomposition of square matrix, $A = QTQ^* = QTQ^{-1}$ where Q is unitary (i.e. $Q^*Q = I$) and T is upper triangular; $Q^* = \overline{Q^T}$ 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 348 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.
104	Cholesky factorization of a square, symmetric, positive definite matrix $A = R^*R$, where R is upper-triangular	`R = chol(A)`	`R = chol(A)`
105	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 $AE = QR$
106	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 $\|\vec{v}\|_p = (\sum \|v_i\|^p)^{1/p}$

No.	Description	MATLAB	R
107	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,0,0)$d)` for 2-norm $\\|A\\|_2$, `norm(A,'i')` for infinity-norm $\\|A\\|_\infty$, and `norm(A,'f')` for Frobenius norm $\left(\sum_i (A^T A)_{ii}\right)^{1/2}$
108	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')`
109	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)
110	Condition number $\text{cond}(A) = \\|A\\|_\infty \\|A^{-1}\\|_\infty$ of A, using infinity-norm	`cond(A,inf)`	`1/rcond(A,'I')`
111	Orthnormal basis for null space of matrix A	`null(A)`	`null(A)` with this function provided by the **pracma** package
112	Orthnormal basis for image/range/column space of matrix A	`orth(A)`	`orth(A)` with this function provided by the **pracma** package
113	Mean of all elements in vector or matrix	`mean(v)` for vectors, `mean(A(:))` for matrices	`mean(v)` or `mean(A)`
114	Means of columns of a matrix	`mean(A)`	`colMeans(A)`
115	Means of rows of a matrix	`mean(A,2)`	`rowMeans(A)`
116	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(A)` for matrices. This normalizes by $n-1$.
117	Standard deviations of columns of a matrix	`std(A)`. This normalizes by $n-1$. Use `std(A,1)` to normalize by n	`apply(A,2,sd)`. This normalizes by $n-1$. Note: in previous versions of R, `sd(A)` computed this.
118	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 $n-1$.
119	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 $n-1$.
120	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 $n-1$.
121	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 $n-1$.
122	Mode of values in vector **v**	`mode(v)` (chooses smallest value in case of a tie), or `[m,f,c]=mode(v); c{1}` (gives list of all tied values)	No simple function built in, but some approaches are: `as.numeric(names(sort(-table(v)))[1]` (chooses smallest value in case of a tie), or `as.numeric(names(table(v))[table(v)==max(sort(table(v)))])` (gives vector of all tied values), or `tmp = unique(v); tmp[which.max(tabulate(match(v, tmp)))]` (in case of a tie, chooses whichever tied value occurs first in **v**)

No.	Description	Matlab	R
123	Median of values in vector **v**	`median(v)`	`median(v)`
124	Basic summary statistics of values in vector **v**	`summary(dataset(v))` Note: only works if **v** is a column vector; use `summary(dataset(v(:)))` to make it work regardless of whether **v** is a row or column vector.	`summary(v)`
125	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)`
126	Covariance matrix, giving covariances between columns of matrix A	`cov(A)`	`var(A)` or `cov(A)`
127	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)`
128	Pearson's linear correlation coefficient between elements of vectors **v** and **w**	`corr(v,w)` Note: **v** and **w** must be column vectors. Or `corr(v(:),w(:))` will work for both row and column vectors.	`cor(v,w)`
129	Kendall's tau correlation statistic for vectors **v** and **w**	`corr(v,w,'type','kendall')`	`cor(v,w,method='kendall')`
130	Spearman's rho correlation statistic for vectors **v** and **w**	`corr(v,w,'type','spearman')`	`cor(v,w,method='spearman')`
131	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
132	Matrix C of pairwise Pearson's correlation coefficients between each pair of columns of matrices A and B, i.e. c_{ij} is 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
133	Sum of all elements in vector or matrix	`sum(v)` for vectors, `sum(A(:))` for matrices	`sum(v)` or `sum(A)`
134	Sums of columns of matrix	`sum(A)`	`colSums(A)`
135	Sums of rows of matrix	`sum(A,2)`	`rowSums(A)`
136	Product of all elements in vector or matrix	`prod(v)` for vectors, `prod(A(:))` for matrices	`prod(v)` or `prod(A)`
137	Products of columns of matrix	`prod(A)`	`apply(A,2,prod)`
138	Products of rows of matrix	`prod(A,2)`	`apply(A,1,prod)`
139	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 348 for how to install/load packages).
140	Cumulative sum of values in vector	`cumsum(v)`	`cumsum(v)`
141	Cumulative sums of columns of matrix	`cumsum(A)`	`apply(A,2,cumsum)`

No.	Description	MATLAB	R
142	Cumulative sums of rows of matrix	`cumsum(A,2)`	`t(apply(A,1,cumsum))`
143	Cumulative sum of all elements of matrix (column-by-column)	`cumsum(A(:))`	`cumsum(A)`
144	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)

145	Cumulative minimum or maximum of elements in vector **v**	`w=zeros(size(v)); w(1)=v(1);`
		`for i=2:length(v)`
		`  w(i)=min(w(i-1),v(i));`
		`end`
		
		This actually runs very efficiently because MATLAB optimizes/accelerates simple **for** loops
			`cummin(v)` or `cummax(v)`

146	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)`

147	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)`
		Or this will also work:
		`y=3*ones(size(x)); y(x>5)=4`
			`y = ifelse(x > 5, 4, 3)`

148	Minimum of values in vector **v**	`min(v)`	`min(v)`
149	Minimum of all values in matrix **A**	`min(A(:))`	`min(A)`
150	Minimum value of each column of matrix **A**	`min(A)` (returns a row vector)	`apply(A,2,min)` (returns a vector)
151	Minimum value of each row of matrix **A**	`min(A, [ ], 2)` (returns a column vector)	`apply(A,1,min)` (returns a vector)
152	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)`
153	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)`
154	Find minimum among all values in matrices **A** and **B**	`min([A(:)  ; B(:)])`	`min(A,B)`
155	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
156	Number of rows in A	`size(A,1)`	`nrow(A)` or `dim(A)[1]`
157	Number of columns in A	`size(A,2)`	`ncol(A)` or `dim(A)[2]`
158	Dimensions of A, listed in a vector	`size(A)`	`dim(A)`
159	Number of elements in vector **v**	`length(v)`	`length(v)`
160	Total number of elements in matrix A	`numel(A)`	`length(A)`
161	Max. dimension of A	`length(A)`	`max(dim(A))`
162	Sort values in vector **v**	`sort(v)`	`sort(v)`
163	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`

164	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.

165	Sort order of rows of matrix **m**, specifying to use columns **x**, **y**, **z** as the sorting "keys"	`sortrows(m, [x y z])`	`m[order(m[,x], m[,y], m[,z]),]`

No.	Description	MATLAB	R
166	Same as previous item, but sort in decreasing order for columns **x** and **y**	`sortrows(m, [-x -y z])`	`m[order(-m[,x], -m[,y], m[,z]),]`
167	Sort order of rows of matrix **m**, and keep indices used for sorting	`[y,i] = sortrows(m)`	`i=order(m[1,]); y=m[i,]`
168	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))`
169	Given vector **v**, return list of indices of elements of **v** which are greater than 5	`find(v > 5)`	`which(v > 5)`
170	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)`
171	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]`
172	Given vector **x**, build a vector containing the unique values in **x** (i.e. with duplicates removed).	`unique(x)` gives the values sorted numerically; `unique(x, 'stable')` gives them in the order they appear in **x**	`unique(x)` gives the values in the order they appear in **x**; `sort(unique(x))` builds a sorted set of unique values
173	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))`
174	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`
175	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
176	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.)
177	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
178	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`

179	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`

180	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`

181	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
182	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.
183	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
184	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.
185	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.
186	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.	No simple built-in way. But this will work: `coef(lm(as.formula(paste('y~',paste('I(x^',1:n,')', sep='',collapse='+')))))` This more concise "lower-level" method will also work: `coef(lm.fit(outer(x,0:n,'^'),y))` Note that both of the above return the coefficients in ascending order. Also see the **polyreg** function in the **mda** package (see item 348 for how to install/load packages).
187	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.
188	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$y`
189	Fit cubic spline using Forsythe, Malcolm and Moler method (third derivatives at endpoints match third derivatives of exact cubics through the four points at each end) to points (x_i, y_i) whose coordinates are in vectors **x** and **y**; evaluate at points whose x coordinates are in vector **xx**, storing corresponding y's in **yy**	I'm not aware of a function to do this in MATLAB	`tmp=spline(x,y,xout=xx); yy=tmp$y`

No.	Description	MATLAB	R
190	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
191	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`
192	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

193	"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

194	"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`
			`}`

195	"if/else" statement	`if cond`
		`  command1`
		`  command2`
		`else`
		`  command3`
		`  command4`
		`end`
		Note: MATLAB also has an "**elseif**" statement, e.g.:
		`if cond1`
		`  commands1`
		`elseif cond2`
		`  commands2`
		`elseif cond3`
		`  commands3`
		`else`
		`  commands4`
		`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 (though see item 147 for something related), but you can do this:
			`if (cond1) {`
			`  commands1`
			`} else if (cond2) {`
			`  commands2`
			`} else if (cond3) {`
			`  commands3`
			`} else {`
			`  commands4`
			`}`

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:

Description	MATLAB	R
a AND b	`a && b`	`a && b`
a OR b	`a || b`	`a || b`
a XOR b	`xor(a,b)`	`xor(a,b)`
NOT a	`~a`	`!a`

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):

Description	MATLAB	R
a AND b	`a & b`	`a & b`
a OR b	`a | b`	`a | b`
a XOR b	`xor(a,b)`	`xor(a,b)`
NOT a	`~a`	`!a`

No.	Description	MATLAB	R
196	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))`
197	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))`
198	Test whether all values in a logical/boolean vector are TRUE	`all(v)`	`all(v)`
199	Test whether any values in a logical/boolean vector are TRUE	`any(v)`	`any(v)`

No.	Description	MATLAB	R

200	"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.)

201	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`

202	"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

203	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.

204	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

205	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 348 for how to install/load packages).

206	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 348 for how to install/load packages).

207	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 348 for how to install/load packages).

6 Probability and random values

No.	Description	MATLAB	R
208	Generate a continuous uniform random value between 0 and 1	`rand`	`runif(1)`
209	Generate vector of n uniform random vals between 0 and 1	`rand(n,1)` or `rand(1,n)`	`runif(n)`
210	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)`
211	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)`
212	Generate a random integer between 1 and k	`randi(k)` or `floor(k*rand)+1`	`floor(k*runif(1)) + 1` or `sample(k,1)`
213	Generate $m \times n$ matrix of discrete uniform random integers between 1 and k	`randi(k, m, n)` or `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` or `matrix(sample(k, m*n, replace=TRUE), m)`
214	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(sample(c(0,1), m*n, replace=TRUE, prob=c(1-p, p)), m)` or `(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.)
215	Generate $m \times n$ matrix where each entry is a with probability p, otherwise is b	`b + (a-b)*(rand(m,n)<p)`	`matrix(sample(c(b,a), m*n, replace=TRUE, prob=c(1-p, p)), m)` or `b + (a-b)*(matrix( runif(m,n),m)<p)`
216	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`	`sample(a:b, 1)` or `floor((b-a+1)*runif(1))+a`

217	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...`
			`}`

218	Generate a random permutation of the integers $1, 2, \ldots, n$	`randperm(n)`	`sample(n)`
219	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)`
220	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,true)`	`w=sample(v,k,replace=TRUE)`

No.	Description	MATLAB	R
221	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)`	`w=sample(v,k,replace=FALSE)`
222	Generate a value from 1 to n with corresponding probabilities in vector **pv**	`sum(rand > cumsum(pv))+1` If entries of **pv** don't sum to one, rescale them first: `sum(rand > cumsum(pv)/sum(pv))+1`	`sample(n, 1, prob=pv)` If the entries of **pv** don't sum to one, **sample** automatically rescales them to do so.
223	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)	`rng(12)` See also **RandStream** for how to create and use multiple streams of random numbers. And note: in versions of MATLAB prior to 7.7, instead use `rand('state', 12)`.	`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
224	Generate a random value from the binomial(n,p) distribution	`binornd(n,p)` or `sum(rand(n,1)<p)` will work even without the Statistics Toolbox.	`rbinom(1,n,p)`
225	Generate a random value from the Poisson distribution with parameter λ	`poissrnd(lambda)`	`rpois(1,lambda)`
226	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)`
227	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)`
228	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)`
229	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)`
230	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)`
231	Generate a random vector from the multinomial distribution, with **n** trials and probability vector **p**	`mnrnd(n,p)`	`rmultinom(1,n,p)`
232	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
233	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 $0 \leq$ **p** ≤ 1.	`dbinom(x,n,p)`
234	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)`
235	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)`
236	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)`
237	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)`
238	Probability that a random variable from the discrete uniform distribution on integers $1 \dots n$ 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`
239	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
240	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)`
241	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)`
242	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)`
243	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)`
244	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)`
245	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
246	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; you can tell R to use it by default by doing `options(device='X11')`. 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 X11 graphics in R 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.
247	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)
248	Determine which figure window is currently active	`gcf`	`dev.cur()`
249	List open figure windows	`get(0,'children')` (The 0 handle refers to the root graphics object.)	`dev.list()`
250	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.
251	Plot points using open circles	`plot(x,y,'o')`	`plot(x,y)`
252	Plot points using solid lines	`plot(x,y)`	`plot(x,y,type='l')` (Note: that's a lower-case 'L', not the number 1)

253	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

254	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
255	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.	`plot(x,y,type='h',lwd=8,lend=1)` You may wish to adjust the line width (the **lwd** parameter).
256	Make histogram of values in **x**	`hist(x)`	`hist(x)`
257	Given vector **x** containing discrete 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)`	`plot(table(x),lwd=8,lend=1)` or `barplot(table(x))` Note that in the latter approach, the bars have the proper labels, but do not actually use the x values as their x coordinates.
258	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))`
259	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 348 for how to install/load packages).
260	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 348 for how to install/load packages).
261	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
262	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, linetypes, 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)`. See the **rgl** package to interactively rotate 3-D plots (and see item 348 for how to load packages).
263	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)`.

264	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)`

265	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 348 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)`.
266	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))`
267	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.
268	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
269	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.
270	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 286 and 287)
271	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.
272	Add a text label to a plot	`text(x,y,'hello')`	`text(x,y,'hello')`
273	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)`
274	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)`
275	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)`
276	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
277	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.
278	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.
279	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))`.
280	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.
281	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 348 for how to load packages). To use a colormap with the latter, do e.g. `levelplot(A,col.regions= terrain.colors(100))`.
282	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
283	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:

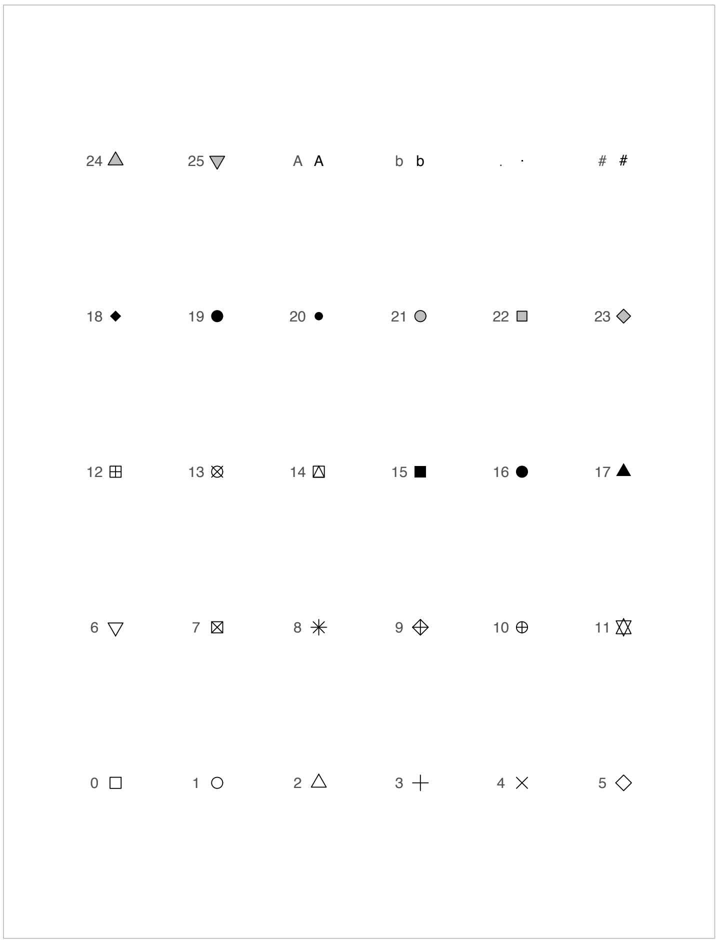
Symbol	Color	Symbol	Marker	Symbol	Linestyle
`b`	blue	`.`	point (.)	`-`	solid line
`g`	green	`o`	circle ($\circ$)	`:`	dotted line
`r`	red	`x`	cross ($\times$)	`-.`	dash-dot line
`c`	cyan	`+`	plus sign ($+$)	`--`	dashed line
`m`	magenta	`*`	asterisk ($*$)		
`y`	yellow	`s`	square ($\Box$)		
`k`	black	`d`	diamond ($\Diamond$)		
`w`	white	`v`	triangle (down) ($\bigtriangledown$)		
		`^`	triangle (up) ($\bigtriangleup$)		
		`<`	triangle (left) ($\triangleleft$)		
		`>`	triangle (right) ($\triangleright$)		
		`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	0	open square	`l`	lines
`'red'`	Red	1	open circle	`b`	both
`'cyan'`	Cyan	2	triangle point-up	`c`	lines part only of "b"
`'magenta'`	Magenta	3	$+$ (plus)	`o`	lines, points overplotted
`'yellow'`	Yellow	4	$\times$ (cross)	`h`	histogram-like lines
`'black'`	Black	5	diamond	`s`	steps
`'#RRGGBB'`	hexadecimal specification of Red, Green, Blue	6	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 (can be useful for setting up axis ranges, etc.)
			(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
284	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.
285	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
286	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')`.) You can also simply use `dev.copy2pdf(file='fname.pdf')`.
287	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()`. The command `dev.copy2eps(file='fname.eps')` also saves in portrait mode.
288	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
289	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
290	Create a folder (also known as a "directory")	`mkdir dirname`	`dir.create('dirname')`
291	Set/change working directory	`cd dirname`	`setwd('dirname')`
292	Get working directory	`pwd`	`getwd()`
293	See list of files in current working directory	`dir`	`dir()`
294	Run commands in file 'foo.m' or 'foo.R' respectively	`foo` But see item 344 for how to tell MATLAB where to look for the file **foo.m**.	`source('foo.R')`
295	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='%'))`
296	Read data from text file "data.txt" into matrix A, skipping the first **s** lines of the file	`tmp=importdata('data.txt', ' ',s);` `a=tmp.data`	`A=as.matrix(read.table( 'data.txt', skip=s))`
297	Write data from matrix A into text file "data.txt"	`save data.txt A -ascii`	`write(t(A), file='data.txt', ncolumn=dim(A)[2])`
298	Save all variables/data in the workspace to a file **foo** (with appropriate suffix)	`save foo.mat` (MATLAB recognizes files with ".mat" suffix as binary save files). Just **save** with no arguments saves to **matlab.mat**	`save.image(file='foo.rda')` (You may use whatever filename suffix you like.) Just `save.image()` with no arguments saves to **.RData**
299	Reload all variables/data from a saved file **foo** (with appropriate suffix)	`load foo.mat`. Just `load` with no arguments tries to load from **matlab.mat**.	`load('foo.rda')`

9 Miscellaneous

9.1 Variables

No.	Description	Matlab	R
300	Assigning to variables	`x = 5`	`x <- 5` or `x = 5` Note: for compatibility with S-plus, many people prefer the first form.
301	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`
302	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.
303	Short list of defined variables	`who`	`ls()`
304	Long list of defined variables	`whos`	`ls.str()`
305	See detailed info about the variable **ab**	`whos ab`	`str(ab)`
306	See detailed info about all variables with "ab" in their name	`whos *ab*`	`ls.str(pattern='ab')`
307	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)`
308	Clear one variable	`clear x`	`rm(x)`
309	Clear two variables	`clear x y`	`rm(x,y)`
310	Clear all variables	`clear all`	`rm(list=ls())`
311	See if variable **x** exists (the commands given can also take more arguments to be more specific)	`exist('x')`	`exists('x')`
312	See what type of object **x** is	`class(x)`	`class(x)`, `typeof(x)`, and `mode(x)` give different aspects of the "type" of **x**
313	(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.
314	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.
315	See how many bytes of memory are used to store a given object **x**	`tmp = whos('x'); tmp.bytes`	`object.size(x)`

9.2 Strings and Misc.

No.	Description	MATLAB	R

316	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.

317	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)
318	Exit the program	`quit` or `exit`	`q()` or `quit()`
319	Comments	`% this is a comment`	`# this is a comment`
320	Display a string	`disp('hi there')` or to omit trailing newline use `fprintf('hi there')`	`print('hi there')` Note: to avoid having double-quotes around the displayed string, do `print('hi there', quote=FALSE)` or `print(noquote('hi there'))`. Or use `cat('hi there')`. But note that use of **cat** in a script won't put newlines at the end of each string. To achieve that, either do `cat('hi there\n')` or `cat('hi there',fill=TRUE)`
321	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")` Also see **cat** in item above.
322	Give prompt and read numerical input from user	`x = input('Enter data:')`	`print('Enter data:'); x=scan()` However, note that if you are executing commands from a file (via the **source** command or some mechanism in R's GUI), **scan** is likely to read its input from the following lines of the file, rather than from the keyboard. Also see **cat** 2 items above.
323	Give prompt and read character (string) input from user	`x = input('Enter string:','s')`	`x = readline('Enter string:')`
324	Concatenate strings	`['two hal' 'ves']`	`paste('two hal', 'ves', sep='')`
325	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='')`
326	Extract substring of a string	`text1='hi there'; text2=text(2:6)`	`text1='hi there'; text2=substr(text1,2,6)`

No.	Description	MATLAB	R
327	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.
328	Find indices of regular expression pattern **p** in string **s**	`v=regexp(s,p)`	`v=gregexpr(p,s)[[1]]` (The returned vector also has a "match.length" attribute giving lengths of the matches; this attribute can be removed via `attributes(v)=NULL`.)

329	Perform some commands only if the regular expression **p** is contained in the string **s**	`if (regexp(s,p)`
		`  ...commands...`
		`end`
			`if (grepl(p,s)) {`
			`  ...commands...`
			`}`

330	Convert number to string	`num2str(x)`	`as.character(x)`

331	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)`

332	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`
333	Pause for x seconds	`pause(x)`	`Sys.sleep(x)`
334	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
335	Produce a beep (or possibly a visual signal, depending on preferences set)	`beep`	`alarm()`
336	Measure CPU time used to do some commands	`t1=cputime; ...commands... ; cputime-t1`	`t1=proc.time(); ...commands... ; (proc.time()-t1)[1]`
337	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]`
338	Print an error message and interrupt execution	`error('Problem!')`	`stop('Problem!')`

No.	Description	MATLAB	R
339	Print a warning message	`warning('Smaller problem!')`	`warning('Smaller problem!')`
340	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.
341	Evaluate contents of a string `s` as command(s).	`eval(s)`	`eval(parse(text=s))`
342	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.
343	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. See item 294 for reading command files in R.
344	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. See item 294 for reading command files in R.

No.	Description	MATLAB	R
345	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).
346	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)
347	Execute a command (such as **date**) in the operating system	`!date`	`system('date')`
348	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 344 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

<table>
<tr><th>No.</th><th>Description</th><th>MATLAB</th><th>R</th></tr>
<tr><td>349</td><td>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.</td><td><code>A = (A | (rand(L) < p))*1;</code></td><td><code>A = (A | (matrix(runif(L^2),L) < p))*1</code></td></tr>
<tr><td>350</td><td>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</td><td><code>A = (A & (rand(L) < 1-p))*1;</code></td><td><code>A = (A & (matrix(runif(L^2),L) < 1-p))*1</code></td></tr>
<tr><td>351</td><td>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.</td><td><code>mod(newx-1,L)+1</code> 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 <code>mod(newx-1+L,L)+1</code></td><td><code>((newx-1) %% L) + 1</code> 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 <code>((newx-1+L)%%L) + 1</code></td></tr>
<tr><td>352</td><td>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.</td><td><code>dx=ix2-ix1+1; dy=iy2-iy1+1;
A(iy1:iy2,ix1:ix2) = ...
(rand(dy,dx) < p0)*1;</code></td><td><code>dx=ix2-ix1+1; dy=iy2-iy1+1;
A[iy1:iy2,ix1:ix2] =
(matrix(runif(dy*dx),dy) <
p0)*1</code></td></tr>
</table>

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