

Package ‘control’

May 8, 2026

Type Package

Title A Control Systems Toolbox

Version 0.2.5

Author Ben C. Ubah [aut, cre]

Maintainer Ben C. Ubah <ubah.ben22@gmail.com>

Imports pracma, expm, signal, Matrix, graphics, stats

Description Solves control systems problems relating to time/frequency response, LTI systems design and analysis, transfer function manipulations, and system conversion.

License GPL-2

BugReports <https://github.com/benubah/control/issues>

LazyData TRUE

RoxygenNote 6.0.1

Suggests testthat

NeedsCompilation no

Repository CRAN

Date/Publication 2017-12-12 09:35:34 UTC

Contents

abcdchk	3
acker	4
append	5
bode	6
c2d	7
care	8
cloop	9
connect	10
ctrb	12
damp	13
dcgain	14
esort	14

feedback	15
freqresp	16
gensig	17
givens_rot	18
impulse	18
initial	20
issiso	22
lsim	22
lsimplot	23
ltifr	24
ltitr	25
nyquist	26
obsv	28
ordschur	28
parallel	29
pid	30
place	31
pole	32
poly2str	33
polysub	34
ramp	34
selectsys	36
series	37
ss	38
ss2tf	39
ss2zp	40
ssdata	42
step	43
TF	44
tf	46
tf2ss	47
tf2zp	48
tfchk	49
tfdata	49
zp2ss	50
zp2tf	51
zpk	52
zpkdata	53

abcdchk *State-space matrices check.*

Description

abcdchk verifies the dimensions of A,B,C,D matrices in its arguments, to ascertain that they are correctly defined.

Usage

```
abcdchk(a, b, c, d)
```

Arguments

a	An n x n matrix
b	An n x m matrix
c	An p x n matrix
d	An p x m matrix

Details

This is a utility function that is always invoked by other functions to ascertain the dimensions of the arguments a,b,c,d and returns a message if there is an ill-defined entry.

Value

Returns an empty string if matrix dimensions are consistent. Otherwise it returns the associated error message

Examples

```
A <- rbind(c(0,1), c(-10000,-4))
B <- rbind(0,1)
C <- rbind(c(1,0), c(0,1))
D <- rbind(0,0)
message <- abcdchk(A,B,C,D)
```

`acker`*Pole placement gain selection using Ackermann's formula*

Description

Computes the Pole placement gain selection using Ackermann's formula.

Usage

```
acker(a, b, p)
```

Arguments

<code>a</code>	State-matrix of a state-space system
<code>b</code>	Input-matrix of a state-space system
<code>p</code>	closed loop poles

Details

`K <- ACKER(A,B,P)` calculates the feedback gain matrix `K` such that the single input system $\dot{x} <- Ax + Bu$

with a feedback law of $u <- -Kx$ has closed loop poles at the values specified in vector `P`, i.e., `P <- eigen(A - B * K)`.

This method is NOT numerically stable and a warning message is printed if the nonzero closed loop poles are greater than 10 in `P`.

Examples

```
F <- rbind(c(0,1),c(0,0))
G <- rbind(0,1)
H <- cbind(1,0);
J <- 0
t <- 1
sys <- ss(F,G, H,J)
A <- c2d(sys,t);
j <- sqrt(as.complex(-1));
pc <- rbind(0.78+0.18*j, 0.78-0.18*j)
K <- acker(A$A, A$B, pc)
```

append

Append the dynamics of a set of systems

Description

append appends the dynamics of a set of n-state-space systems together

Usage

```
append(...)
```

Arguments

... Variable argument for LTI system models of tf, ss or zpk class

Details

append(sys1, sys2, sys3, ... sysN) first combines the the first two systems and then goes on to combine the resulting state-space system to the next system and so forth. This is achieved by calling the sysgroup(sys1, sys2) at each iteration to group the systems in consecutive pairs until all systems are completely appended to form one system.

sysgroup(sys1, sys2) appends only two systems and is used by append

If a system is not in state-space representation, the function tries to form a state-space representation for such system.

Value

The function returns a state-space model of the formed appended system with A, B, C, D matrices

See Also

[series parallel feedback connect](#)

Examples

```
sys1 <- ss(1,2,3,4)
sys2 <- ss(2,3,4,5)
sys3 <- ss(6,7,8,9)
append(sys1, sys2, sys3)
sys4 <- tf(1, c(1,2,5))
append(sys1, sys2, sys4)
```

 bode

Bode Frequency Response for continuous-time Linear Systems.

Description

bode computes the magnitude and phase of the frequency response of system `sys` at given frequencies `w`

General Usage:

```
bode(sys)
```

```
bode(sys, w)
```

```
bode(sys, w, iu)
```

```
bode(sys, w = seq(0, 100, length = 10000), iu = 1)
```

```
bodeplot(sys)
```

```
bodeplot(sys, w)
```

```
bodeplot(sys, w, subtitle)
```

Usage

```
bode(sys, w, iu)
```

Arguments

<code>sys</code>	LTI system of transfer-function, state-space and zero-pole classes
<code>w</code>	vector of range of frequencies at the response is computed in rad/sec
<code>iu</code>	number to specify an input for a MIMO state-space system. If the system has 3 inputs, then <code>iu</code> would be set to 1, set to 2 and then to 3 to obtain the bode response from input 1, 2, and 3 to the outputs. For single input systems, <code>iu</code> is always set to 1. <code>iu</code> is not needed/allowed for calls to <code>bodeplot</code>

Details

bode Compute the magnitude and phase of the frequency response of system `sys` at given frequencies `w`. When `sys` is a transfer function, bode computes the frequency response of the system using the `signal` package.

`bodeplot` plots the frequency response computed by `bode`. For a MIMO state-space system, `bodeplot` uses `selectsys` to obtain the bode response for each input-to-output pair and plot them individually. This means that for a 2-input, 2-output system, `bodeplot` obtains the response for input 1 to output 1, input 1 to output 2, input 2 to output 1 and input 2 to output 2. `bodeplot` uses the `subtitle` argument to allow a user assign the plot a sub-title

Value

A list is returned by calling `bode` containing: `w` - frequencies

`mag` - magnitude of the response

`phase` - phase of the response

A plot is returned by calling `bodeplot`

See Also

[nyquist](#)

Examples

```
bode(tf(100, c(1,6,100)))
bode(ssdata(tf(100, c(1,6,100))))

bode(tf(4, c(1,1)))
A <- rbind(c(-2, -1), c(1,0)); B <- rbind(1,0);
C <- cbind(0,1); D <- as.matrix(0);
bode(ss(A,B,C,D))

## MIMO plot
A1 <- rbind(c(0,1), c(-25,-4)); B1 <- rbind(c(1,1), c(0,1))
C1 <- rbind(c(1,0), c(0,1)); D1 <- rbind(c(0,0), c(0,0))
sys1 <- ss(A1,B1,C1,D1)
bodeplot(sys1)
# Use: par(mfrow = c(2,1)); bodeplot(selectsys(sys1,1,2)) to obtain the response for a subsystem
# of sys1 for input 1 and output 2 only
# RESET your plot layout using par(mfrow = c(1,1))
```

c2d

Continuous Time model conversion to Discrete Time model.

Description

`c2d` converts a system in continuous-time model to a discrete time model

Usage

```
c2d(sys, t)
```

Arguments

`sys` An object of transfer function, state-space or zero-pole class

`t` Sample time; a numeric value greater than 0

Details

c2d converts the continuous-time system: $x = Ax + Bu$ to the discrete-time state-space system: $x[n+1] = \Phi * x[n] + \Gamma * u[n]$ based on the method of assuming a zero-order hold on the inputs and sample time. Transfer function and zero-pole systems are converted to state-space representation before conversion to discrete-time.

Value

Returns the provided system (transfer function, state-space or zero-pole) in an equivalent discrete-time.

See Also

[ltitr](#)

Examples

```
## for TF
c2d(tf(c(1,-1), c(1,4,5)), 0.1)
## for ZPK
sys <- zpkdata( tf(c(1,-1), c(1,4,5)) )
c2d(sys, 0.1)
c2d(zpkdata( tf(c(1,-1), c(1,4,5)) ), 0.1)
```

care

Continuous-time Algebraic Riccati Equation solution

Description

Computes the unique solution to the continuous-time Riccati equation:

$$A^* X + X^* A - X^* B * R^{-1} * B^* * X + Q^* Q = 0$$

Usage

```
care(A, B, Q, R = 1)
```

Arguments

A	State-matrix of a state-space system
B	Input-matrix of a state-space system
Q	Symmetric output-matrix of a state-space system
R	Single number

Details

$X \leftarrow \text{care}(A, B, Q, R)$ returns the stabilizing solution (if it exists) to the continuous-time Riccati equation.

The `care` function also returns the gain matrix, G and a vector, L of the closed-loop eigenvalues, where

$$G = R^{-1} B' X E$$

$$L = \text{eig}(a - b * g)$$

Value

Returns the stabilizing matrix, gain and closed-loop eigenvalues in a list.

Note

A, B must be controllable

Examples

```
a <- matrix(c(-3, 2, 1, 1), byrow = TRUE, ncol = 2)
b <- matrix(c(0, 1), nrow = 2)
c <- matrix(c(1, -1), ncol = 2)
q <- t(c)%*%c
r <- 3
care(a, b, q, r)
```

cloop

Closed Feedback Loops

Description

`cloop` forms a closed feedback loop for a state-space or transfer function system

Usage

```
cloop(sys, e, f)
```

Arguments

<code>sys</code>	LTI system model of transfer-function or state-space model
<code>e</code>	inputs vector
<code>f</code>	outputs vector

Details

Other possible usages of `cloop`:

```
cloop(sys)
```

```
cloop(sys, sgn)
```

If `sys` is a state-space model, `cloop(sys, SGN)` produces a state-space model of the closed-loop system obtained by feeding all the outputs of the system to all the inputs. Positive feedback is used when `SGN < 1` and negative when `SGN < -1`.

If `sys` is a transfer function model, `cloop(sys, SGN)` produces the SISO closed loop system in transfer function form obtained by unity feedback with the sign `SGN`.

`cloop(sys, OUTPUTS, INPUTS)` forms the closed loop system obtained by feeding the specific outputs into specific outputs. The vectors `OUTPUTS` and `INPUTS` contain indices into the outputs and inputs of the system respectively. Positive feedback is assumed. To form closed loop with negative feedback, negative values are used in the vector `INPUTS`.

Value

Returns a closed feedback loop system

See Also

[feedback](#)

Examples

```
J <- 2.0; b <- 0.04; K <- 1.0; R <- 0.08; L <- 1e-4
P <- TF("K/(s*((J*s + b)*(L*s + R) + K^2))")
cloop(P)
cloop(ss(1,2,3,4))
```

connect

Block diagram interconnections of dynamic systems

Description

`connect` is used to form a state-space model of a system from its block diagram.

Usage

```
connect(sysapp, q, inputs, outputs)
```

Arguments

sysapp	A state-space system containing several appended systems returned from the append function. All appended systems must be in state-space model.
q	Matrix that specifies the interconnections of the block diagram. Each row specifies a connection. The first element of each row is the number of the block. The other following elements of each row specify where the block gets its summing inputs, with negative elements used to indicate minus inputs to the summing junction. For example: <code>cbind(2,1,3)</code> means that block 2 has an input from block 1 and block 3
inputs	A column matrix specifying the inputs of the resulting aggregate system
outputs	A column matrix specifying the outputs of the resulting aggregate system

Details

`connect` This function requires calling the [append](#) function to group a set of unconnected dynamics system in one system object. It then uses the `q` matrix to determine the interconnections between the systems and finally specifies the inputs and outputs for the new aggregate system. This approach helps to realize a block diagram as a single system on which further analysis could be performed. See examples below.

Value

Returns the interconnected system, returned as either a state-space model

See Also

[append series parallel feedback](#)

Examples

```
a1 <- rbind(c(0, 0), c(1,-3))
b1 <- rbind(-2,0)
c1 <- cbind(0,-1)
d <- as.matrix(0)
a2 <- as.matrix(-5)
b2 <- as.matrix(5)
c2 <- as.matrix(1)
d2 <- as.matrix(0)
sysa1 <- ss(a1, b1, c1, d)
sysa2 <- ss(a2, b2, c2, d2)
a1 <- append(sysa1, sysa2)
connect(a1, cbind(2,1,0), cbind(1,2), cbind(1,2))
## OR
connect(append(sysa1, sysa2), cbind(2,1,0), cbind(1), cbind(2))
## Not run:
cbind(2,1,0) means that block 2 has an input from block 1 and block 0 (which doesnt exist)
cbind(1) means that block 1 is the input of the system, and cbind(2) means block 2 is the
output of the system.
if we replace cbind(2) with cbind(1,2), this means that the system has two outputs from
block 1 and 2
```

```
i.e. \code{connect(append(sysa1, sysa2), cbind(2,1,0), cbind(1), cbind(1,2))}
## End(Not run)
```

ctrb

Form Controllability Matrix

Description

ctrb forms the controllability matrix.

Usage

```
ctrb(A, B)
```

Arguments

A	State matrix, A
B	State matrix, B

Details

ctrb(a, b) returns the controllability matrix, $[B \ AB \ A^2B \ \dots \ A^{(n-1)}B]$. If the Controllability matrix has full row rank, the system is controllable.

Value

Returns the controllability matrix.

See Also

[obsv](#)

Examples

```
a1 <- rbind(c(0,0),c(1,-3))
b1 <- rbind(-2,0)
ctrb(a1, b1)
```

Description

damp computes the natural frequency and damping for continuous systems.

Usage

```
damp(sys, doPrint = TRUE)
```

Arguments

sys	A Continuous-time system of state-space, transfer-function or zero-pole-gain model.
doPrint	If TRUE prints out the results. Default is TRUE.

Details

A table of the eigenvalues of the matrix a , the associated damping factors, the associated natural frequency (rad/s and Hz.) is displayed by calling the function.

When the continuous system is a state-space model, the eigenvalues of the state matrix are obtained and sorted. If the system is a transfer-function, the poles of the systems are obtained and sorted. For zero-pole systems, the poles are just extracted and sorted. The sorted eigenvalues are printed to output and used to obtain the natural frequencies and damping factors.

Value

Returns the natural frequencies and damping factors in a list:

omegan = Natural Frequencies (rad/s) zeta = Damping Factors

See Also

[esort](#)

Examples

```
sys1 <- tf(1, c(1,2,5))  
damp(sys1)
```

`dcgain`*DC Gain*

Description

`dcgain` Forms the Givens rotation matrix

Usage

`dcgain(sys)`

Arguments

`sys` A transfer function or state-space model

Details

`dcgain(sys)` Computes the steady-state gain (or low frequency gain) of a continuous system.

Value

Returns the gain.

`esort`*Sort Complex Continuous Eigenvalues in Descending Order*

Description

`esort` sorts the complex continuous eigenvalues in descending order

Usage

`esort(p)`

Arguments

`p` A vector containing the poles of a transfer-function, zero-pole model or the eigenvalues of a state-matrix

Details

`esort` sorts the complex eigenvalues based on their real part. The unstable eigenvalues (positive real part) are first shown.

This function is used to sort eigenvalues and system poles in [damp](#)

Value

Returns the sorted eigenvalues and the corresponding indices in a list:

s = sorted eigenvalues idx = index

See Also

[damp](#)

 feedback

Feedback Connection of LTI systems

Description

feedback forms a feedback connection for two LTI state-space or transfer function systems

Usage

```
feedback(sys1, sys2, in1, out1)
```

Arguments

sys1	LTI system model of transfer-function or state-space model
sys2	LTI system model of transfer-function or state-space model
in1	vector of inputs
out1	vector of outputs

Details

When `sys1` and `sys2` are transfer functions `feedback(sys1, sys2, SIGN)` produces the SISO closed loop system in transfer function form obtained by connecting the two SISO transfer function systems in feedback with the sign `SIGN`.

`feedback(sys1, sys2, SIGN)` produces an aggregate state-space system consisting of the feedback connection of the two systems 1 and 2. If `SIGN = 1` then positive feedback is used. If `SIGN = -1` then negative feedback is used. In all cases, the resulting system has the same inputs and outputs as system 1.

`feedback(sys1, sys2, inputs, outputs)` produces the feedback system formed by feeding all the outputs of system2 into the inputs of system 1 specified by `INPUTS1` and by feeding the outputs of system 2 specified by `OUTPUTS1` into all the inputs of system 2. Positive feedback is assumed. To connect with negative feedback, use negative values in the vector `INPUTS1`.

`feedback()` calls `fdbcksys()` to perform the feedback connection for two systems. Unity feedback calls are possible, for example, `feedback(sys1, 1)`, `feedback(1, sys1)`

Value

Returns the feedback system in `tf` or `ss` model

See Also

[cloop parallel series](#)

Examples

```
C <- pid(350,300,50)
P <- TF(" 1/(s^2 + 10* s + 20)")
feedback(C,P)
feedback(P,P,1)
feedback(P,P,-1)
feedback(P,P)
feedback(P,1)
feedback(TF("C*P"))
## Not run: On Octave: feedback(C*P)
```

freqresp

Low level frequency response function

Description

This function obtains the low level frequency response of a system.

Usage

```
freqresp(sys, w = seq(0, 100, length = 10000), iu = 1)
```

Arguments

<code>sys</code>	An LTI system of <code>tf</code> , <code>ss</code> and <code>zpk</code> class
<code>w</code>	a vector of frequency points
<code>iu</code>	For calls to <code>freqresp</code> , <code>iu</code> is a number specifying an input for a MIMO state-space system. If the system has 3 inputs, then <code>iu</code> would be set to 1, set to 2 and then to 3 to obtain the step response from input 1, 2, and 3 to the outputs

Value

`freqresp(sys, w)` returns a vector of frequencies for `sys` in complex form

See Also

[bode nyquist](#)

Examples

```
H <- freqresp(ssdata(tf(c(1,1), c(1,2,1))), (seq(0, 100, length = 10000)))
H <- freqresp(tf(c(1,1), c(1,2,1)), seq(0, 100, length = 10000))
```

gensig *Generate periodic signal*

Description

gensig generates a periodic signal. More useful when used in combination with `lsim`

Usage

```
gensig(signal, tau, tfinal, tsam)
```

Arguments

signal	A string input containing either values of: square, sin, cos, pulse in the following format: 'sq' or 'square' - Square wave 'si' or 'sine' - Sine wave 'co' or 'cos' - Cosine wave 'pu' or 'pulse' - Periodic pulse
tau	Duration of one period in seconds. Default is 5
tfinal	Duration of the signal in seconds. Default is 30
tsam	sampling time in seconds. Default is 0.01

Details

gensig generates a periodic signal of the following types: square, sin, cos, pulse
Possible usage: `gensig(signal)`

Value

Returns a list of two single column matrices, u and t
u is the vector of signal values
t is the time vector of the signal

See Also

[lsim](#)

Examples

```
## Not run: A square wave signal
sig <- gensig('square', 4, 10, 0.1)
plot(sig$t, sig$u, type = "l", col = "blue")
grid(5,5, col = "lightgray")

## Not run: A sine wave signal
```

```
sig <- gensig('sin')
plot(sig$t, sig$u, type = "l", col = "blue")
grid(5,5, col = "lightgray")
```

givens_rot

Complex Givens Rotation

Description

givens_rot Forms the Givens rotation matrix

Usage

```
givens_rot(a, b)
```

Arguments

a	Complex Square-matrix
b	complex Input-matrix

Details

givens_rot(a, b) returns the complex Givens rotation matrix This function is called by [ordschur](#)

Value

Returns the complex Givens rotation matrix.

See Also

[ordschur](#)

impulse

Impulse Response for Linear Systems

Description

impulse obtains the impulse response of the linear system:

$$dx/dt = Ax + Bu$$

$$y = Cx + Du$$

to an impulse applied to the input

Usage

```
impulse(sys, t, input)
impulseplot(sys, t, input)
```

Arguments

sys	LTI system of transfer-function, state-space and zero-pole classes
t	Time vector. If not provided, it is automatically set.
input	For calls to <code>impulse</code> , <code>input</code> is a number specifying an input for a MIMO state-space system. If the system has 3 inputs, then <code>input</code> would be set to 1, set to 2 and then to 3 to obtain the impulse response from input 1, 2, and 3 to the outputs. For single input systems, <code>input</code> is always set to 1. For calls to <code>impulseplot</code> , <code>input</code> is a vector or range for a MIMO state-space system. For example, <code>input <- 1:3</code> for a system with 3-inputs

Details

`impulse` produces the impulse response of linear systems using `lsim`

`impulseplot` produces the impulse response as a plot against time.

These functions can handle both SISO and MIMO (state-space) models.

Other possible calls using `impulse` and `impulseplot` are:

```
impulse(sys)
impulse(sys, t)
impulseplot(sys)
impulseplot(sys, t)
```

Value

A list is returned by calling `impulse` containing:

- t Time vector
- x Individual response of each x variable
- y Response of the system

The matrix `y` has as many rows as there are outputs, and columns of the same size of `length(t)`. The matrix `x` has as many rows as there are states. If the time vector is not specified, then the automatically set time vector is returned as `t`

A plot of `y` vs `t` is returned by calling `impulseplot`

See Also

[initial step ramp](#)

Examples

```

res <- impulse(tf(1, c(1,2,1)))
res$y
res$t
impulse(tf(1, c(1,2,1)), seq(0, 10, 0.1))
impulseplot(tf(1, c(1,2,1)))
impulseplot(tf(1, c(1,2,1)), seq(0, 10, 0.1))

## Not run: State-space MIMO systems
A <- rbind(c(0,1), c(-25,-4)); B <- rbind(c(1,1), c(0,1));
C <- rbind(c(1,0), c(0,1)); D <- rbind(c(0,0), c(0,0))
res1 <- impulse(ss(A,B,C,D), input = 1)
res2 <- impulse(ss(A,B,C,D), input = 2)
res1$y # has two rows, i.e. for two outputs
res2$y # has two rows, i.e. for two outputs
impulseplot(ss(A,B,C,D), input = 1:2) # OR
impulseplot(ss(A,B,C,D), input = 1:ncol(D))
impulseplot(ss(A,B,C,D), seq(0,3,0.01), 1:2)

```

initial

Initial Condition Response for Linear Systems

Description

initial obtains the time response of the linear system:

$$dx/dt = Ax + Bu$$

$$y = Cx + Du$$

to an initial condition.

Usage

```

initial(sys, x0, t)
initialplot(sys, x0, t)

```

Arguments

sys	LTI system of transfer-function, state-space and zero-pole classes
x0	initial conditions as a column vector. Should have as many rows as the rows of A. where x0 is not specified, random values are assigned
t	regularly spaced time vector. If not provided, it is automatically set. For calls to initialplot, the same arguments are allowed

Details

`initial` produces the time response of linear systems to initial conditions using `lsim`

`initialplot` produces the time response to initial conditions as a plot against time.

The functions can handle both SISO and MIMO (state-space) models.

Other possible calls using `initial` and `initialplot` are:

```
initial(sys)
```

```
initial(sys, x0)
```

```
initialplot(sys)
```

```
initialplot(sys, x0)
```

Value

A list is returned by calling `initial` containing:

`x` Individual response of each `x` variable

`y` Response of the system

`t` Time vector

The matrix `y` has as many rows as there are outputs, and columns of the same size of `length(t)`.

The matrix `X` has as many rows as there are states. If the time vector is not specified, then the automatically set time vector is returned as `t`

A plot of `y` vs `t` is returned by calling `initialplot`

See Also

[step impulse ramp](#)

Examples

```
res <- initial(tf(1, c(1,2,1)))
res$y
res$t
A <- rbind(c(-2, -1), c(1,0)); B <- rbind(1,0);
C <- cbind(0,1); D <- as.matrix(0);
x0 <- matrix(c( 0.51297, 0.98127))
initialplot(ss(A,B,C,D), x0)
initialplot(tf(1, c(1,2,1)), t = seq(0, 10, 0.1))

## Not run: State-space MIMO systems
A <- rbind(c(0,1), c(-25,-4)); B <- rbind(c(1,1), c(0,1));
C <- rbind(c(1,0), c(0,1)); D <- rbind(c(0,0), c(0,0))
res <- initial(ss(A,B,C,D))
res$y # has two rows, i.e. for two outputs
initialplot(ss(A,B,C,D))
```

 issiso

SISO / MIMO Check

Description

issiso checks if state-space system is a single-input single-output system ismimo checks if state-space system is a multiple-input multiple-output system

Usage

```
issiso(sys)
```

Arguments

sys Dynamic system of state-space model

Value

Returns TRUE or FALSE

lsim

Time response of a Linear system

Description

lsim Computes the time response of a Linear system described by:

$$\dot{x} = Ax + Bu$$

$$y = Cx + Du$$

to the input time history u.

Usage

```
lsim(sys, u, t, x0)
```

Arguments

sys An LTI system of tf, ss and zpk class

u A row vector for single input systems. The input u must have as many rows as there are inputs in the system. Each column of U corresponds to a new time point. u could be generated using a signal generator like gensig

t time vector which must be regularly spaced. e.g. seq(0, 4, 0.1)

x0 a vector of initial conditions with as many rows as the rows of a

Details

`lsim(sys, u, t)` provides the time history of the linear system with zero-initial conditions.

`lsim(sys, u, t, x0)` provides the time history of the linear system with initial conditions. If the linear system is represented as a model of `tf` or `zpk` it is first converted to state-space before linear simulation is performed. This function depends on `c2d` and `ltitr`

Value

Returns a list of two matrices, `x` and `y`. The `x` values are returned from `ltitr` call.

See Also

`ltitr` `lsimplot`

Examples

```
signal <- gensig('square',4,10,0.1)
H <- tf(c(2, 5, 1),c(1, 2, 3))
response <- lsim(H, signal$u, signal$t)
plot(signal$t, response$y, type = "l", main = "Linear Simulation Response", col = "blue")
lines(signal$t, signal$u, type = "l", col = "grey")
grid(5,5, col = "lightgray")
## Not run: based on example at: https://www.mathworks.com/help/ident/ref/lsim.html

## Not run: MIMO system response
A <- rbind(c(0,1), c(-25,-4)); B <- rbind(c(1,1), c(0,1))
C <- rbind(c(1,0), c(0,1)); D <- rbind(c(0,0), c(0,0))
response <- lsim(ss(A,B,C,D), cbind(signal$u, signal$u), signal$t)
plot(signal$t, response$y[1,], type = "l",
     main = "Linear Simulation Response", col = "blue"); grid(7,7)
plot(signal$t, response$y[2,], type = "l",
     main = "Linear Simulation Response", col = "blue"); grid(7,7)
```

lsimplot

Plot time response of an LTI system

Description

`lsimplot` Plots the time response of a Linear system described by:

$$x = Ax + Bu$$

$$y = Cx + Du$$

to the input time history `u`.

Usage

`lsimplot(sys, u, t, x0)`

Arguments

<code>sys</code>	An LTI system of <code>tf</code> , <code>ss</code> and <code>zpk</code> class
<code>u</code>	A row vector for single input systems. The input <code>u</code> must have as many rows as there are inputs in the system. Each column of <code>u</code> corresponds to a new time point. <code>u</code> could be generated using a signal generator such as <code>gensig</code>
<code>t</code>	time vector which must be regularly spaced. e.g. <code>seq(0, 4, 0.1)</code>
<code>x0</code>	a vector of initial conditions with as many rows as the rows of <code>sys\$A</code>

Details

`lsimplot(sys, u, t)` plots the time history of the linear system with zero-initial conditions.

`lsimplot(sys, u, t, x0)` plots the time history of the linear system with given initial conditions.

If the linear system is represented as a model of `tf` or `zpk` it is first converted to state-space before linear simulation is performed. This function depends on `c2d` and `ltitr`

Value

Returns a plot for the response of the system

See Also

[lsim](#) [stepplot](#) [rampplot](#)

Examples

```
signal <- gensig('square',4,10,0.1)
H <- tf(c(2, 5, 1),c(1, 2, 3))
lsimplot(H, signal$u, signal$t)

## Not run: MIMO system response
A <- rbind(c(0,1), c(-25,-4)); B <- rbind(c(1,1), c(0,1))
C <- rbind(c(1,0), c(0,1)); D <- rbind(c(0,0), c(0,0))
lsimplot(ss(A,B,C,D), cbind(signal$u, signal$u), signal$t)
```

ltifr

LTI frequency response kernel

Description

This function computes the frequency response of the following system:

$$g(w) = (wI - A) \setminus B$$

for the complex frequencies contained in the vector `W`. The column vector `B` must have as many rows as the matrix `A`.

Usage

```
ltifr(A, B, w)
```

Arguments

A	State-space matrix, A
B	State-space input-matrix, B. B must have as many rows as the matrix A.
w	Vector of complex frequencies

Value

Returns the frequency response in vector. [freqresp](#) utilizes this function for state-space systems.

See Also

[freqresp](#)

Examples

```
## use \code{\link{freqresp}}
```

ltitr	<i>Time response of a Linear Time-Invariant system</i>
-------	--

Description

ltitr Computes the time response of a Linear Time-Invariant system

Usage

```
ltitr(a, b, u, x0)
```

Arguments

a	An n x n matrix of the state-space system
b	An n x m matrix of the state-space system
u	A row vector for single input systems. The input U must have as many rows as there are inputs in the system. Each column of U corresponds to a new time point. u could be generated using a signal generator like gensig
x0	a vector of initial conditions with as many rows as the rows of a

Details

ltitr computes the time response of a Linear Time-Invariant system in state-space representation of the form: $x[n+1] = Ax[n] + Bu[n]$ to an input, U

ltitr(a, b, u) computes the time response with zero-initial conditions since x0 is not supplied.

Value

Returns a matrix X which has as many rows as there are outputs y (and with $\max(\dim(U))$ columns).

See Also

[lsimgsig](#)

Examples

```
A <- diag(1, 2)
B <- rbind(1, 1)
x0 <- rbind(-1, -2)
u <- cbind(1, 2, 3, 4, 5)
X <- ltitr(A, B, u)
X <- ltitr(A, B, u, x0)
```

```
A <- replicate(6, abs(rnorm(6)))
B <- replicate(3, abs(rnorm(6)))
U <- replicate(100, rnorm(3))
x0 <- rnorm(6)
X <- ltitr(A, B, U)
X <- ltitr(A, B, U, x0)
```

nyquist

Nyquist Frequency Response for continuous-time Linear Systems.

Description

nyquist computes the real and imaginary parts of the frequency response of system `sys` at given frequencies `w`

Usage

```
nyquist(sys, w, iu)
```

Arguments

<code>sys</code>	LTI system of transfer-function, state-space and zero-pole classes
<code>w</code>	vector of range of frequencies at the response is computed in rad/sec
<code>iu</code>	number to specify an input for a MIMO state-space system. If the system has 3 inputs, then <code>iu</code> would be set to 1, set to 2 and then to 3 to obtain the nyquist response from input 1, 2, and 3 to the outputs. For single input systems, <code>iu</code> is always set to 1. <code>iu</code> is not needed/allowed for calls to <code>nyquistplot</code>

Details

nyquist Compute the real and imaginary parts of the frequency response of system `sys` at given frequencies `w`. When `sys` is a transfer function, `nyquist` computes the frequency response of the system using the signal package.

nyquistplot plots the frequency response computed by `nyquist`. For a MIMO state-space system, `nyquistplot` uses `selectsys` to obtain the nyquist response for each input-to-output pair and plot them individually. This means that for a 2-input, 2-output system, `nyquistplot` obtains the response for input 1 to output 1, input 1 to output 2, input 2 to output 1 and input 2 to output 2. `nyquistplot` uses the `subtitle` argument to allow a user assign the plot a sub-title

Other possible calls using `nyquist` and `nyquistplot` are:

```
nyquist(sys) nyquist(sys, w) nyquist(sys, w = seq(0, 100, length = 10000), iu = 1) nyquistplot(sys)
nyquistplot(sys, w) nyquistplot(sys, w, subtitle)
```

Value

A list is returned by calling `nyquist` containing: `h.real` - real part of the frequency response

`h.imag` - imaginary part of the frequency response

A plot is returned by calling `nyquistplot`

See Also

[bode](#)

Examples

```
nyquist(tf(100, c(1,6,100)))
nyquist(ssdata(tf(100, c(1,6,100))))

## Not run: MIMO plot
A1 <- rbind(c(0,1), c(-25,-4)); B1 <- rbind(c(1,1), c(0,1))
C1 <- rbind(c(1,0), c(0,1)); D1 <- rbind(c(0,0), c(0,0))
sys1 <- ss(A1,B1,C1,D1)
nyquistplot(sys1)
## Not run: Use nyquistplot(selectsys(sys1,1,2)) to obtain the response for a subsystem
of sys1 for input 1 and output 2 only.

RESET your plot layout using par(mfrow = c(1,1))

## End(Not run)
```

obsv	<i>Observability Matrix</i>
------	-----------------------------

Description

This function creates the observability matrix.

Usage

```
obsv(A, C)
```

Arguments

A	State-space matrix, A
C	State-space matrix, C

Value

obsv(A, C) returns the observability matrix, obsvm. where $\text{obsvm} = [C \ CA \ CA^2 \ \dots \ CA^{(n-1)}]$

See Also

[ctrb](#)

Examples

```
A <- rbind(c(0,1), c(-25,-4))
C <- rbind(c(1,0), c(0,1))
obsv(A, C)
```

ordschur	<i>Ordered schur decomposition</i>
----------	------------------------------------

Description

ordschur Orders a schur decomposition

Usage

```
ordschur(Ui, Si, idx)
```

Arguments

Ui	Square upper-triangular matrix from schur decomposition. If Ui is not given it is set to the identity matrix.
Si	Orthogonal matrix from schur decomposition
idx	array index

Details

ordschur finds an orthogonal matrix, U so that the eigenvalues appearing on the diagonal of Si are ordered according to the increasing values of the array index where the i-th element of index corresponds to the eigenvalue appearing as the element Si[i, i].

ordschur could also be used in this syntax: ordschur(Si, idx)

Value

Returns a list of ordered (U, S)

parallel	<i>Parallel Connection of two systems</i>
----------	---

Description

parallel connects two systems in the parallel block form below

$$\begin{array}{c} \text{[System1]} \\ \text{[System2]} \end{array} \begin{array}{c} \text{u} \\ \text{0} \end{array} \rightarrow \text{y}$$

Usage

parallel(sys1, sys2, in1, in2, out1, out2)

Arguments

sys1	LTI system object of tf, ss or zpk class
sys2	LTI system object of tf, ss or zpk class
in1	Numeric vector containing indexes to the inputs of sys1
in2	Numeric vector containing indexes to the inputs of sys2
out1	Numeric vector containing indexes to the outputs of sys1
out2	Numeric vector containing indexes to the outputs of sys2

Details

`psys <- parallel(sys1, sys2)` produces a state- space system consisting of the parallel connection of `sys1` and `sys2` that connects all the inputs together and sums all the outputs of the two systems.

The parallel connection is performed by appending the two systems, summing the specified inputs and outputs, and removing the, now redundant, inputs and outputs of system 2.

If `sys1` and `sys2` are transfer functions, then `parallel(sys1, sys2)` produces a parallel connection of the two transfer function systems.

`parallel(sys1, sys2, IN1, IN2, OUT1, OUT2)` connects the two systems in parallel by connecting the inputs specified by `IN1` and `IN2` and by summing the outputs specified by `OUT1` and `OUT2`. The vector `IN1` contains indexes into the input vectors of `sys1` while, `IN2` contains indexes for `sys2`, . Vectors `OUT1` and `OUT2` contain indexes for the outputs of the `sys1` and `sys2` respectively.

Value

The function returns a state-space model of the parallel-connected system with A, B, C, D matrices

See Also

[series feedback connect](#)

Examples

```
sys2 = ss(1,2,3,4)
sys3 = ss(6,7,8,9)
parallel(sys2, sys3)
parallel(tf(1, c(1,2,3)), ss(1,2,3,4))
parallel(tf(1, c(1,2,3)),tf(2, c(3,2,3)))
```

pid

Proportional-Integral-Derivative (PID) Controller

Description

pid Parallel form of the model of a PID controller

Usage

```
pid(p, i, d)
```

Arguments

p	Proportional gain. A real and finite value.
i	Integral gain. A real and finite value. set this to zero for PD and P-control
d	Derivative gain. A real and finite value. set this to zero for PI and P-control

Details

pid creates the transfer function model for a PID, PI, PD, and P-controller.

Value

Returns a transfer function model for the PID, PI, PD or P-controller.

Examples

```
C <- pid(350,300,50) # PID-control
P <- TF(" 1/(s^2 + 10* s + 20)")
T <- feedback(TF("C*P"), 1)
stepplot(T, seq(0,2,0.01))
```

```
C <- pid(300,0,0) # P-control
T <- feedback(TF("C*P"), 1)
stepplot(T, seq(0,2,0.01))
```

```
C <- pid(30,70,0) # PI-control
T <- feedback(TF("C*P"), 1)
stepplot(T, seq(0,2,0.01))
```

```
C <- pid(300,0,10) # PD-control
T <- feedback(TF("C*P"), 1)
stepplot(T, seq(0,2,0.01))
```

place

Pole placement gain selection

Description

Computes the Pole placement gain selection using Ackermann's formula.

Usage

```
place(a, b, p)
```

Arguments

a	State-matrix of a state-space system
b	Input-matrix of a state-space system
p	closed loop poles

Details

`K <- place(A,B,P)` calculates the feedback gain matrix `K` such that the single input system $\dot{x} <- Ax + Bu$

with a feedback law of $u <- -Kx$ has closed loop poles at the values specified in vector `P`, i.e., `P <- eigen(A - B * K)`. This function is just a wrapper for the `acker` function.

This method is NOT numerically stable and a warning message is printed if the nonzero closed loop poles are greater than 10 in `P`.

Examples

```
F <- rbind(c(0,1),c(0,0))
G <- rbind(0,1)
H <- cbind(1,0);
J <- 0
t <- 1
sys <- ss(F,G, H,J)
A <- c2d(sys,t);
j <- sqrt(as.complex(-1));
pc <- rbind(0.78+0.18*j, 0.78-0.18*j)
K <- place(A$A, A$B, pc)
```

pole

Obtain Poles for a System

Description

This function obtains the poles for a given system

Usage

```
pole(sys)
```

Arguments

`sys` LTI system of `tf`, `ss` and `zpk` class

Details

`pole` returns the poles for a given system either a transfer function, state-space or zero-pole models. If `sys` is a transfer function, it computes the roots of the denominator. If `sys` is a state-space object, it computes the eigenvalues of the `A` matrix. If `sys` is a `zpk` object, it retrieves the poles from the object.

Value

The function returns a column matrix containing the poles for the given system

Examples

```
H1 <- tf(c(2, 5, 1),c(1, 3, 5))
pole(zpk(NULL, c(-1,-1), 1))
pole(ssdata(tf(1, c(1,2,1))))
```

poly2str

Print Polynomial

Description

Print polynomial as a character string.

Usage

```
poly2str(p, svar = "x", smul = "*", d = options("digits")$digits)
```

Arguments

p	numeric vector representing a polynomial
svar	character representing the unknown, default x.
smul	multiplication symbol, default *.
d	significant digits, default options("digits").

Details

Modified from package **pracma**. Modification: To hide any coefficient and power that is equal to 1 So that instead of '1s^3' we have 's^3' and instead of 's^1', we have 's'

Value

Returns the usual string representing a polynomial in mathematics.

Examples

```
poly2str(c(2, -3, 1, 20, -11))
```

 polysub

Subtracting Polynomials

Description

Subtract two polynomials given as vectors

Usage

```
polysub(a, b)
```

Arguments

a Vector representing first polynomial.
 b Vector representing second polynomial.

Details

Simply calls polyadd from pracma package in the following manner: `pracma::polyadd(a, -b)`

Value

Returns a Vector representing the resulting polynomial.

Examples

```
polysub(c(1, 1, 1), 1)
polysub(c(1, 1, 1), c(0, 0, 1))
```

 ramp

Ramp Response for Linear Time-Invariant Systems

Description

ramp obtains the ramp response of the linear system:

$$dx/dt = Ax + Bu$$

$$y = Cx + Du$$

Usage

```
ramp(sys, t, input)
rampplot(sys, t, input)
```

Arguments

<code>sys</code>	LTI system of transfer-function, state-space and zero-pole classes
<code>t</code>	Time vector. If not provided, it is automatically set.
<code>input</code>	For calls to <code>ramp</code> , <code>input</code> is a number specifying an input for a MIMO state-space system. If the system has 3 inputs, then <code>input</code> would be set to 1, set to 2 and then to 3 to obtain the ramp response from input 1, 2, and 3 to the outputs. For single input systems, <code>input</code> is always set to 1. For calls to <code>rampplot</code> , <code>input</code> is a vector or range for a MIMO state-space system. For example, <code>input <- 1:3</code> for a system with 3-inputs

Details

`ramp` produces the ramp response of linear systems using `lsim`

`rampplot` produces the ramp response as a plot against time.

These functions can handle both SISO and MIMO (state-space) models.

#' Other possible calls using `ramp` and `rampplot` are:

```
ramp(sys)
```

```
ramp(sys, t)
```

```
rampplot(sys)
```

```
rampplot(sys, t)
```

Value

A list is returned by calling `ramp` containing:

`t` Time vector

`x` Individual response of each `x` variable

`y` Response of the system

The matrix `y` has as many rows as there are outputs, and columns of the same size of `length(t)`. The matrix `x` has as many rows as there are states. If the time vector is not specified, then the automatically set time vector is returned as `t`

A plot of `y` vs `t` is returned by calling `rampplot`

See Also

[initial step impulse](#)

Examples

```
res <- ramp(tf(1, c(1,2,1)))
res$y
res$t
ramp(tf(1, c(1,2,1)), seq(0, 6, 0.1))
rampplot(tf(1, c(1,2,1)))
rampplot(tf(1, c(1,2,1)), seq(0, 6, 0.1))
```

```
## Not run: State-space MIMO systems
A <- rbind(c(0,1), c(-25,-4)); B <- rbind(c(1,1), c(0,1));
C <- rbind(c(1,0), c(0,1)); D <- rbind(c(0,0), c(0,0))
res1 <- ramp(ss(A,B,C,D), input = 1)
res2 <- ramp(ss(A,B,C,D), input = 2)
res1$y # has two rows, i.e. for two outputs
res2$y # has two rows, i.e. for two outputs
rampplot(ss(A,B,C,D), input = 1:2) # OR
rampplot(ss(A,B,C,D), input = 1:ncol(D))
rampplot(ss(A,B,C,D), seq(0,3,0.01), 1:2)
```

selectsys

Select/Remove Subsystem in State-space Model

Description

selectsys extracts a subsystem from a larger state-space system. removesys removes specified inputs, outputs, and state from a state-space system.

Usage

```
selectsys(statesys, inputs, outputs, states)
removesys(statesys, inputs, outputs, states)
```

Arguments

statesys	LTI system model of state-space model
inputs	single integer or vector specifying the particular inputs to be selected/removed
outputs	single integer or vector specifying the particular outputs to be selected/removed
states	single integer or vector specifying the particular states to be selected/removed

Details

subsys <- selectsys(statesys, inputs, outputs) will extract a state space subsystem with the specified inputs and outputs.

subsys <- selectsys(statesys, inputs, outputs, states) will return the state space subsystem with the specified inputs, outputs, and states.

subsys <- removesys(statesys, inputs, outputs) will remove the specified inputs and outputs from the system.

subsys <- removesys(statesys, inputs, outputs, states) will also return a state-space model with the specified inputs, outputs, and states removed from the system.

Value

Returns a subsystem of the state-space model

See Also[append](#)**Examples**

```

A <- rbind(c(33,2,5), c(23,200,2), c(9,2,45))
B <- rbind(c(4,5), c(12,5), c(82,1))
C <- rbind(c(34,56,2), c(6,2,112))
D <- rbind(c(2,0), c(0,19))
sys1 <- ss(A, B, C, D)
selectsys(sys1, 1, 1) # extract subsystem for only input 1 and output 1
selectsys(sys1, 2,2) # extract subsystem for only input 2 and output 2
selectsys(sys1, 2, 1:2) # extract subsystem for only input 1 and output 1 to 2
selectsys(sys1, 1:2, 2) # extract subsystem for only input 1 to 2 and output 2 to 2
selectsys(sys1, 2, 2, 1:2) # extract subsystem for only input 2 and output 2 but states 1 to 2
removesys(sys1, 1,2) # removes input 1 and output 2

```

series

*Series Connection of two systems***Description**

series connects two systems in the series block form below

$$u \rightarrow [\text{System1}] \rightarrow [\text{System2}] \rightarrow y$$
Usage

```
series(sys1, sys2, outputs, inputs)
```

Arguments

sys1	LTI system object of tf, ss or zpk class
sys2	LTI system object of tf, ss or zpk class
outputs	vector of outputs
inputs	vector of inputs

Details

series(sys1, sys2) connects the two state-space systems in series such that the outputs of sys1 specified are connected to the inputs of sys2 specified by input2. If sys1 and sys2 are both transfer functions, series(systf1, systf2) produces the SISO system in transfer function form obtained by connecting the two SISO transfer function systems in series. If a system is not in state-space representation, the function tries to form a state-space representation for such system.

Value

The function returns a state-space model of the aggregate system with A, B, C, D matrices

See Also

[parallel feedback connect](#)

Examples

```
series(tf(1, c(1,2,3)), tf(2, c(2,3,5)))  
sys2 = ss(1,2,3,4)  
sys3 = ss(6,7,8,9)  
series(sys2, sys3)  
series(tf(1, c(1,2,3)), ss(1,2,3,4))
```

ss

Create State-space Model.

Description

ss creates the model for a system represented in state-space form

Usage

```
ss(A, B, C, D, Ts = NULL)
```

Arguments

A	An $n \times n$ matrix
B	An $n \times m$ matrix
C	An $p \times n$ matrix
D	An $p \times m$ matrix
Ts	Sample time for discrete time systems

Details

ss creates a model object for state-space systems.

Value

Returns a list object of 'ss' class.

See Also

[tf zpk](#)

Examples

```

A <- rbind(c(-2, -1), c(1,0))
B <- rbind(1,0)
C <- cbind(0,1)
D <- 0;
sys <- ss(A,B,C,D)

## Not run:  OR

sys <- ss(c(-2,-1,1,0), c(1,0), c(0,1), 0)

## Not run:  Access individual state-space sys elements as

sys$A
sys$B
sys$C
sys$D

```

ss2tf

State-space model conversion to Transfer function model.

Description

ss2tf converts the model for a state-space system to transfer function representation

Usage

```
ss2tf(a, b, c, d, iu)
```

Arguments

a	An n x n matrix
b	An n x m matrix
c	An p x n matrix
d	An p x m matrix
iu	A numeric value denoting number of inputs. default value is 1. For example, if the system has three inputs (u1, u2, u3), then iu must be either 1, 2, or 3, where 1 implies u1, 2 implies u2, and 3 implies u3.

Details

ss2tf converts a model object in state-space form to transfer function model by calculating the transfer function of the system: $\dot{x} = Ax + Bu$ $y = Cx + Du$

#' Other possible usages for ss2tf are: `ss2tf(a,b,c,d)` `ss2tf(sys)` `ss2tf(sys, iu)`

where sys is an object of state-space class

Value

Returns an object of 'tf' class containing num and den. The numerator coefficients are returned in matrix num with as many rows as outputs y.

See Also

[tf2ss](#) [ss2zp](#)

Examples

```
sys2 <- tf2ss(tf(1, c(1,2,1)))
ss2tf(sys2)

## Not run:  OR

ss2tf(sys2$A,sys2$B,sys2$C,sys2$D)

# a single input multiple output system
A <- rbind(c(0,1), c(-10000,-4)); B <- rbind(0,1); C <- rbind(c(1,0), c(0,1));
D <- rbind(0,0)
ss2tf(A, B, C, D)

# a MIMO system
A = rbind(c(0,1), c(-25,-4)); B = rbind(c(1,1), c(0,1));
C = rbind(c(1,0), c(0,1)); D = rbind(c(0,0), c(0,0))
ss2tf(A,B,C,D,1) # to obtain output for input 1
ss2tf(A,B,C,D,2) # to obtain output for input 2

## OR

systems <- vector("list", ncol(D))
for(i in 1:ncol(D)){ systems[[i]] <- ss2tf(A,B,C,D,i) }
systems
systems[[1]]
systems[[2]]
```

ss2zp

State-space representation to zero-pole-gain representation

Description

ss2zp converts a system represented in state-space form to zero-pole-gain model

Usage

```
ss2zp(a,b,c,d,iu)
```

Arguments

a	An $n \times n$ matrix
b	An $n \times m$ matrix
c	An $p \times n$ matrix
d	An $p \times m$ matrix
iu	A numeric value denoting number of inputs. default value is 1. For example, if the system has three inputs (u1, u2, u3), then iu must be either 1, 2, or 3, where 1 implies u1, 2 implies u2, and 3 implies u3.

Details

ss2zp converts a system represented in zero-pole form to state-space by converting from zero-pole to transfer function and from transfer function to state-space. The vector P contains the pole locations of the denominator of the transfer function.

Other possible usages for ss2zp are:

```
ss2zp(a,b,c,d)
```

```
ss2zp(sys)
```

```
ss2zp(sys, iu)
```

where sys is an object of state-space class

Value

Returns a list object of 'zpk' class, consisting of z, p and k. The numerator zeros are returned in the columns of matrix Z with number of columns equal to number of outputs. The gains for each numerator transfer function are returned in column vector K. P, a column vector contains the pole locations of the denominator of the transfer function.

See Also

[zp2ss](#) [ss2tf](#)

Examples

```
A <- rbind(c(-2, -1), c(1,0)); B <- rbind(1,0);
C <- cbind(0,1); D <- 0;
sys2 <- ss(A,B,C,D)
ss2zp(sys2$A,sys2$B,sys2$C,sys2$D)
ss2zp( zp2ss ( tf2zp( c(1,1,1), c(1,2,1) ) ) ) )

## Not run: A MIMO system
A = rbind(c(0,1), c(-25,-4)); B = rbind(c(1,1), c(0,1));
C = rbind(c(1,0), c(0,1)); D = rbind(c(0,0), c(0,0))
ss2tf(A,B,C,D,1) # to obtain output for input 1
ss2tf(A,B,C,D,2) # to obtain output for input 2

## Not run: OR
```

```
systems <- vector("list", ncol(D))
for(i in 1:ncol(D)){ systems[[i]] <- ss2zp(A,B,C,D,i) }
systems
systems[[1]]
systems[[2]]
```

ssdata

Retrieve State-space data

Description

ssdata retrieves the model for a state-space system from a sys object

Usage

```
ssdata(sys1)
```

Arguments

sys1 an LTI system object of tf, ss or zpk classes

Details

ssdata retrieves a model object for a state-space system, from a sys object of tf, ss and zpk classes

Value

Returns a list object of ss class containing A, B, C and D matrices

See Also

[ss](#) [tfdata](#) [zpkdata](#)

Examples

```
sys1 <- tf(c(1), c(1,2,1))
ssdata(sys1)
A <- rbind(c(-2, -1), c(1,0)); B <- rbind(1,0);
C <- cbind(0,1); D <- 0;
sys2 <- ss(A,B,C,D)
ssdata(sys2)
ss2zp(ssdata(zpk(NULL, c(-1,-1), 1)))
```

Description

step obtains the time response of the linear system:

$$dx/dt = Ax + Bu$$

$$y = Cx + Du$$

Usage

```
step(sys, t, input)
stepplot(sys, t, input)
```

Arguments

sys	LTI system of transfer-function, state-space and zero-pole classes
t	Time vector. If not provided, it is automatically set.
input	For calls to step, input is a number specifying an input for a MIMO state-space system. If the system has 3 inputs, then input would be set to 1, set to 2 and then to 3 to obtain the step response from input 1, 2, and 3 to the outputs. For single input systems, input is always set to 1. For calls to stepplot, input is a vector or range for a MIMO state-space system. For example, input <- 1:3 for a system with 3-inputs

Details

step produces the step response of linear systems using lsim

stepplot produces the step response as a plot againsts time.

The functions can handle both SISO and MIMO (state-space) models.

Other possible calls using step and stepplot are:

```
step(sys)
step(sys, t)
stepplot(sys)
stepplot(sys, t)
```

Value

A list is returned by calling `step` containing:

- x Individual response of each x variable
- y Response of the system
- t Time vector

The matrix `y` has as many rows as there are outputs, and columns of the same size of `length(t)`. The matrix `X` has as many rows as there are states. If the time vector is not specified, then the automatically set time vector is returned as `t`

A plot of `y` vs `t` is returned by calling `stepplot`

See Also

[initial impulse ramp](#)

Examples

```
res <- step(tf(1, c(1,2,1)))
res$y
res$t
step(tf(1, c(1,2,1)), seq(0, 10, 0.1))
stepplot(tf(1, c(1,2,1)))
stepplot(tf(1, c(1,2,1)), seq(0, 10, 0.1))

## Not run:  State-space MIMO systems

A <- rbind(c(0,1), c(-25,-4)); B <- rbind(c(1,1), c(0,1));
C <- rbind(c(1,0), c(0,1)); D <- rbind(c(0,0), c(0,0))
res1 <- step(ss(A,B,C,D), input = 1)
res2 <- step(ss(A,B,C,D), input = 2)
res1$y # has two rows, i.e. for two outputs
res2$y # has two rows, i.e. for two outputs
stepplot(ss(A,B,C,D), input = 1:2) # OR
stepplot(ss(A,B,C,D), input = 1:ncol(D))
```

 TF

Evaluate Transfer function Expressions

Description

TF Evaluates a given transfer function expression in the s-domain

Usage

TF(str_expr)

Arguments

`str_expr` String expression containing the transfer function

Details

TF Evaluates a given transfer function polynomial expression in the s-domain. The evaluation of the expressions are performed similar to symbolic math computations for polynomials. A transfer function model is created as the result of the expression evaluation. Thus, this is an alternative way of creating transfer function models following the natural math expressions found in block diagrams. It also provides an alternative way to perform system interconnections. Only transfer function models are currently supported for system interconnection using this function. System interconnections for other models could be performed using the `series`, `parallel`, `feedback` or `connect` functions. See the Examples section for further details.

Value

Returns an object of 'tf' class list with a transfer function. Numerator and denominator coefficients could then be retrieved from the object the same way as any other tf object

See Also

[tf tf2ss series parallel](#)

Examples

```
# Example taken from the GitHub page of Julia Control - an electric motor example
J <- 2.0
b <- 0.04
K <- 1.0
R <- 0.08
L <- 1e-4
P <- TF("K/(s*((J*s + b)*(L*s + R) + K^2))")
Cls <- TF("P/(1 + P)") # closed-loop connection

# More examples
TF("s+1")
sys1 <- tf(1, c(1, 2, 5))
sys2 <- tf(2, c(1, 2, 5))
TF("sys1 + sys2") # parallel system interconnection
TF("sys1 * sys2") # series system interconnection
TF("sys1 - sys2")
TF("sys1 - 1")
TF("sys1 + 1")
TF("sys1 - sys2 + sys2")
TF("sys1 / sys2 / sys2")
```

tf *Create Transfer function Model.*

Description

tf creates the model for a transfer function

Usage

```
tf(num, den, Ts = NULL)
```

Arguments

num	A numeric vector or matrix (for multivariable systems)
den	A numeric vector or matrix (for multivariable systems)
Ts	Sample time for discrete time systems

Details

tf creates a model object for a transfer function, Where num is the numerator and den is the denominator of the transfer function.

Value

Returns an object of 'tf' class list with a proper transfer function or with warnings when not proper.

See Also

[ss](#) [zpk](#) [TF](#) [tf2ss](#) [tf2zp](#)

Examples

```
tf(1, c(1,2,1))
sys1 <- tf(1, c(1,2,1))
sys1$num
sys1$den
```

```
## Not run: for single-input multi-output systems (SIMO) each numerator row for one output
num = rbind(c(0,1,1), c(1,0,1))
den = rbind(c(1,3,2))
tf(num, den)
```

`tf2ss`*Transfer function model conversion to State-space model.*

Description

`tf2ss` converts the model for a transfer function to state-space representation

Usage

```
tf2ss(num, den)
```

Arguments

<code>num</code>	A numeric vector containing the coefficients of the
<code>den</code>	A numeric vector containing the coefficients of the

Details

`tf2ss` converts a model object for a transfer function to a state-space model, Where `num` is the numerator and `den` is the denominator of the transfer function and `sys` is a transfer function object

Another possible call is `tf2ss(sys)` where `sys` is object of transfer-function model.

Value

Returns an object of 'ss' class.

See Also

[ss2tf](#) [tf2zp](#)

Examples

```
tf2ss(tf(1, c(1,2,1)))  
  
## Not run: OR  
  
sys <- tf(1, c(1,2,1))  
tf2ss(sys)  
  
## Not run: OR  
  
sys2 <- tf2ss(1, c(1,2,1))
```

`tf2zp`*Transfer function model conversion to Zero-Pole-Gain model.*

Description

`tf2zp` converts the model for a transfer function to zero-pole-gain representation

Usage

```
tf2zp(num, den)
```

Arguments

<code>num</code>	A numeric vector containing the coefficients of the
<code>den</code>	A numeric vector containing the coefficients of the

Details

`tf2zp` converts a model object for a transfer function to a zero-pole model, Where `num` is the numerator and `den` is the denominator of the transfer function and `sys` is a transfer function object

Another possible call is: `tf2zp(sys)`

where `sys` is an object of transfer-function model.

Value

Returns a list object of 'zpk' class.

See Also

[tf2ss](#) [zp2tf](#)

Examples

```
syszp1 <- tf2zp(c(1,1), c(1,2,1))
syszp1
syszp2 <- tf2zp(c(2,2,1), c(1,2,1))
syszp2
unclass(syszp2) # to see list of the zeros,poles and gain as vectors
tf2zp(zp2tf(c(-1,-1), c(-1,-2), 5))
```

tfchk	<i>Transfer function check.</i>
-------	---------------------------------

Description

tfchk verifies the structure of a transfer function

Usage

```
tfchk(num, den)
```

Arguments

num	A numeric vector
den	A numeric vector

Details

This is a utility function that is always invoked by other functions to verify the structure of num, den. Where num is the numerator and den is the denominator of the transfer function. If the transfer function is not proper, it returns a list with $\text{length}(\text{num}) = \text{length}(\text{den})$.

Value

Returns a list with a proper transfer function or with warnings when not proper.

Examples

```
tf1 <- tfchk(1, c(1,2,1))
```

tfdata	<i>Retrieve Transfer function data</i>
--------	--

Description

tfdata retrieves the model for a transfer function from a sys object

Usage

```
tfdata(sys1)
```

Arguments

sys1	an LTI system object of tf, ss or zpk classes
------	---

Details

tfdata retrieves a model object for a transfer function, from a sys object of tf, ss and zpk classes

Value

Returns a list object of tf class containing numerator and denominator coefficients in descending values of s. For multiple-input multiple-output systems (MIMO) a list containing tf sys objects for as many outputs is returned

See Also

[tf](#) [ssdata](#) [zpkdata](#)

Examples

```
sys1 <- zpk(NULL, c(-1,-1), 1)
tfdata(sys1)
A <- rbind(c(-2, -1), c(1,0)); B <- rbind(1,0);
C <- cbind(0,1); D <- 0
tfdata( ss(A, B, C, D) )
tfdata(ss2zp( A,B,C,D))
tfdata(tf(c(1), c(1,2,1)))

## Not run: MIMO system
A = rbind(c(0,1), c(-25,-4)); B = rbind(c(1,1), c(0,1));
C = rbind(c(1,0), c(0,1)); D = rbind(c(0,0), c(0,0))
tfdata(ss(A,B,C,D))
```

zp2ss

Convert Zero-Pole-Gain Model to State-Space Model

Description

zp2ss converts a system represented in zero-pole form to state-space

Usage

```
zp2ss(z,p,k)
```

Arguments

z	Zero, a vector or single row matrix
p	Pole, a vector or single row matrix
k	Gain, a vector

Details

zp2ss converts a system represented in zero-pole form to state-space by converting from zero-pole to transfer function and from transfer function to state-space

Another possible usage is: zp2ss(sys)

where sys is an object of zero-pole-gain model.

Value

Returns a list object of 'ss' class.

See Also

[ss2zp](#) [zp2tf](#)

Examples

```
zp2ss(NULL, c(-1,-1), 1)
zp2ss(tf2zp(c(1,1,1), c(1,2,1)))
```

 zp2tf

Zero-pole-gain model conversion to Transfer function model

Description

zp2tf converts the model for a zero-pole-gain system to transfer function representation

Usage

```
zp2tf(z, p, k)
```

Arguments

z	A numeric vector containing zero locations
p	A numeric vector containing pole locations
k	A numeric vector for gain

Details

zp2tf converts a model object for a zero-pole-gain system to a transfer function model

Another possible usage is: zp2tf(sys)

where sys is an object of zero-pole-gain model.

Value

Returns a list object of 'tf' class.

See Also[zp2ss](#) [tf2zp](#)**Examples**

```
systf <- zp2tf(zpk(NULL, c(-1,-1), 1))
zp2tf(tf2zp(c(2,2,1), c(1,2,1)))
```

zpk

Create Zero-Pole-Gain Model.

Description

zpk creates the model for a system represented in zero-pole form

Usage

```
zpk(zero, pole, gain, Ts = NULL)
```

Arguments

zero	A vector
pole	A vector
gain	A vector
Ts	Sample time for discrete time systems

Details

zpk creates a model object for zero-pole systems.

Value

Returns a list object of 'zpk' class.

See Also[ss tf](#)

Examples

```
sys <- zpk(NULL, c(-1,-1), 1)
sys <- zpk(c(1,2), c(3,4), 5)
sys <- zpk(c(1,2), c(3+1i,4+2i), 5)

## Not run:  Access individual sys elements as
sys$z
sys$p
sys$k
```

zpkdata	<i>Retrieve zero-pole data from LTI system object</i>
---------	---

Description

zpkdata retrieves the model for a zero-pole-gain system from a sys object

Usage

```
zpkdata(sys1)
```

Arguments

sys1 an LTI system object of tf, ss or zpk classes

Details

zpkdata retrieves a model object for a zero-pole-gain system, from a sys object of tf, ss and zpk classes

Value

Returns a list object of zpk class containing zero, pole and gain matrices. For multivariable systems, the zeros of each system is listed as a column in the zeros matrix, the poles are listed as a column-vector as well as the gain

See Also

[zpk tfdata ssdata](#)

Examples

```
sys1 <- zpk(NULL, c(-1,-1), 1)
zpkdata(sys1)
sys3 <- tf(c(1), c(1,2,1))
zpkdata(sys3)

## Not run:  MIMO system of 2-inputs and 2-outputs
```

```
A = rbind(c(0,1), c(-25,-4)); B = rbind(c(1,1), c(0,1));
C = rbind(c(1,0), c(0,1)); D = rbind(c(0,0), c(0,0))
zpkdata(ss(A,B,C,D))

## OR
syszp <- zpkdata(ss(A,B,C,D))
syszp[[1]]
syszp[[2]]
syszp[[1]]$z # retrieve zeros of system 1 - Input 1 to Outputs 1 and 2
syszp[[2]]$z # retrieve zeros of system 2 - Input 2 to Outputs 1 and 2
```

Index

abcdchk, 3
acker, 4
append, 5, 11, 37

bode, 6, 16, 27
bodeplot (bode), 6

c2d, 7
care, 8
cloop, 9, 16
connect, 5, 10, 30, 38
ctrb, 12, 28

damp, 13, 14, 15
dcgain, 14

esort, 13, 14

fdbcksys (feedback), 15
feedback, 5, 10, 11, 15, 30, 38
freqresp, 16, 25

gensig, 17, 26
givens_rot, 18

impulse, 18, 21, 35, 44
impulseplot (impulse), 18
initial, 19, 20, 35, 44
initialplot (initial), 20
ismimo (issiso), 22
issiso, 22

lsim, 17, 22, 24, 26
lsimplot, 23, 23
ltifr, 24
ltitr, 8, 23, 25

nyquist, 7, 16, 26
nyquistplot (nyquist), 26

obsv, 12, 28

ordschur, 18, 28

parallel, 5, 11, 16, 29, 38, 45
pid, 30
place, 31
pole, 32
poly2str, 33
polysub, 34

ramp, 19, 21, 34, 44
rampplot, 24
rampplot (ramp), 34
removesys (selectsys), 36

selectsys, 36
series, 5, 11, 16, 30, 37, 45
ss, 38, 42, 46, 52
ss2tf, 39, 41, 47
ss2zp, 40, 40, 51
ssdata, 42, 50, 53
step, 19, 21, 35, 43
stepplot, 24
stepplot (step), 43
sysgroup (append), 5

TF, 44, 46
tf, 38, 45, 46, 50, 52
tf2ss, 40, 45, 46, 47, 48
tf2zp, 46, 47, 48, 52
tfchk, 49
tfdata, 42, 49, 53

zp2ss, 41, 50, 52
zp2tf, 48, 51, 51
zpk, 38, 46, 52, 53
zpkdata, 42, 50, 53