

Manual for Package: mathematics

Revision 28M

Karl Kästner

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1 calendar

1.1 days_per_month

1.2 isnight

2 mathematics

mathematical functions of various kind

2.1 cast_byte_to_integer

cast byte to integer

3 complex-analysis

operations on complex numbers

3.1 complex_exp_product_im_im

product of the imaginary part of two complex exponentials

the product has two frequency components

input :
 c : complex amplitudes
 o : frequencies
output :
 cp : amplitude of the product
 op : frequencies of the product

3.2 complex_exp_product_im_re

product of the imaginary part of one and the real part of a second complex exponential

the product has two frequency components

input :
 c : complex amplitudes
 o : frequencies

output :
 cp : amplitude of the product
 op : frequencies of the product

3.3 complex_exp_product_re_im

the product has two frequency components

product of the imaginary part of one and the real part of a second
 complex exponential

input :
 c : complex amplitudes
 o : frequencies
 output :
 cp : amplitude of the product
 op : frequencies of the product

3.4 complex_exp_product_re_re

product of the real part of two complex exponentials

$$\begin{aligned} \text{re}(c1 \exp(i o1 x)) * \text{re}(c2 \exp(i o2 x)) = \\ 1/2 * (\text{real}(c1 * c2 * \exp(i * (n1 + n2) * o * x)) \dots \\ + \text{real}(\text{conj}(c1) * c2 * \exp(i * (n2 - n1) * o * x))) \end{aligned}$$

the product has two frequency components

input :
 c : complex amplitudes
 o : frequencies
 output :
 cp : amplitude of the product
 op : frequencies of the product

3.5 croots

nth-roots of a complex number

input:
 c : complex number

n : order of root
n must be rational, to obtain n solutions
otherwise no finite set of solutions exists

r : roots of the complex number

3.6 root_complex

root of a complex number

3.7 test_imroots

4 derivation

derivation of several functions by means of symbolic computation

4.1 derive_acfar1

4.2 derive_ar1_spectral_density

4.3 derive_ar2param

4.4 derive_arc_length

4.5 derive_fourier_power

4.6 `derive_fourier_power_exp`

4.7 `derive_laplacian_curvilinear`

4.8 `derive_laplacian_fourier_piecewise_linear`

4.9 `derive_logtripdf`

4.10 `derive_phase_drift_inv`

4.11 `derive_smooth1d_parametric`

4.12 `derive_spectral_density_bandpass_initial_condition`

5 `derivation/master`

5.1 `derive_bc_one_sided`

5.2 `derive_convergence`

5.3 `derive_error_fdm`

5.4 `derive_fdm_poly`

5.5 `derive_fdm_power`

5.6 `derive_fdm_taylor`

5.7 `derive_fdm_vargrid`

5.8 `derive_fem_2d_mass`

5.9 `derive_fem_error_2d`

5.10 `derive_fem_error_3d`

5.11 `derive_fem_sym_2d`

5.12 `derive_grid_constants`

5.13 `derive_interpolation`

5.14 `derive_laplacian`

5.15 `derive_limit`

5.16 `derive_nc_1d`

5.17 `derive_nc_1d_`

5.18 `derive_nc_2d`

5.19 `derive_nonuniform_symmetric`

%

5.20 `derive_richardson`

5.21 `derive_sum`

5.22 `nn`

5.23 `test_derive`

5.24 `test_derive_fdm_poly`

5.25 `test_filter`

5.26 `test_vargrid`

6 `derivation`

derivation of several functions by means of symbolic computation

6.1 `simplify_atan`

symbolic simplification of the arcus tangent

7 `mathematics`

mathematical functions of various kind

7.1 `entropy`

8 `finance`

8.1 `derive_skewrnd_walsh_paramter`

8.2 gbb_geostd_entire_series

8.3 gbb_mean

8.4 gbb_simulate

8.5 gbb_std

8.6 gbm_bridge

8.7 gbm_cdf

8.8 gbm_fit

8.9 gbm_fit_old

8.10 gbm_geomean

8.11 gbm_geostd

8.12 `gbm_inv`

8.13 `gbm_mean`

8.14 `gbm_mean_entire_series`

8.15 `gbm_median`

8.16 `gbm_moment2par`

8.17 `gbm_moment2par_entire_series`

8.18 `gbm_pdf`

8.19 `gbm_simulate`

8.20 `gbm_skewness`

8.21 `gbm_std`

8.22 `gbm_std_entire_series`

8.23 `gbm_transform_time_step`

8.24 `put_price_black_scholes`

8.25 `skewgbm_simulate`

8.26 `skewrnd_walsh`

9 `finance/test`

9.1 `test_gbm`

9.2 `test_gbm_pdf`

9.3 `test_skewrnd_walsh`

10 `fourier/@STFT`

10.1 `STFT`

class for short time fourier transform

Note: the interval T_i should be set to at least $2 \cdot \max(T)$, as
otherwise coefficients

tend to oscillate in the presence of noise

Note: for convenience, the independent variable is labeled as time
(t),

but the independent variable is arbitrary, so it works
likewise in space

10.2 `itransform`

inverse of the short time fourier transform

10.3 `stft_`

static wrapper for `STFT`

10.4 `stftmat`

transformation matrix for the short time fourier transform

10.5 `transform`

short time fourier transform

11 `fourier`

support and analysis functions both for the discrete (fast) fourier
transform (dft/fft)

and continuous fourier analysis (fourier series)

11.1 amplitude_from_peak

amplitude and standard deviation of the amplitude of a frequency component

represented by a peak in the fourier domain

input :

h : peak height

w : peak width at half height

output:

a : amplitude in real space

s : standard deviation of the frequency (!)

11.2 caesaro_weight

11.3 dftmtx_man

fourier matrix in matlab style with a limited number of rows, columns of higher frequencies are omitted

input :

n : number of samples

nr : number of columns

output :

F : fourier matrix

11.4 example_fourier_window

11.5 fft2_cartesian2radial

11.6 fft_man

fast fourier transform for complex input data

input:

F : data in real space

output :

F : fourier transformation of F

11.7 `fft_rotate`

11.8 `fftsmooth`

smooth the fourier transform and determine upper and lower bound confidence intervals

input :

f :

sfunc : a smoothing function (for example fir convolution with rectangular window)

returns filtered (mean) value and normalized fir window

nf : window length

nsigma : number of standard deviations for confidence intervals

output :

ff : filtered fourier transform

l : lower bound

u : upper bound

11.9 `fix_fourier`

fill gaps (missing data) by means of fourier extrapolation

fix periodic data series with fourier interpolation

longest gap should not exceed 1/2 of the shortest time span of interest (1/cutoff frequency)

note: this limit equals the position of first side lobe of the ft of a rectangular window with gap length

11.10 `fourier_2d_padd`

11.11 `fourier_2d_quadrants`

11.12 `fourier_axis`

return axis of frequencies and periods for the discrete fourier transform
as computed by fft (matlab-style)

input:

X : sample locations (equal interval)

L : length of samples

n : number of samples

output :

f : frequencies

T : periods

mask : mask for 1/2 of the fourier transform
(as both halves are complex conjugates)

N : frequency id

11.13 `fourier_axis_2d`

frequency axis of the 2d fourier transform as computed by Matlab
function [fx, fy, fr, ft, Tx, Ty, mask, N] = `fourier_axis_2d`(L,n)

11.14 `fourier_cesaro_correction`

11.15 `fourier_coefficient_piecewise_linear`

fourier series coefficients of a piecewise linear function
(not coefficient of discrete fourier transform)
function can be discontinuous between intervals
scales domain length to 2π

input :
 l,r : end points of piecewise linear function
 lval, rval : values at end points
 L : length of domain
 n : number of samples/highest frequency

 output :
 a, b : coefficients for frequency components

11.16 `fourier_coefficient_piecewise_linear_1`

fourier series coefficients of a piecewise linear function
 (not coefficient of discrete fourier transform)
 function can be discontinuous between intervals
 scales domain length to 2π

input :
 X : end points of piecewise linear function
 Y : values at end points

 output :
 ab : coefficients for frequency components

11.17 `fourier_coefficient_ramp3`

fourier series coefficient of a ramp

11.18 `fourier_coefficient_ramp_pulse`

fourier series coefficient of a ramp pules

11.19 `fourier_coefficient_ramp_step`

fourier coefficient of a ramp-step

11.20 `fourier_coefficient_square_pulse`

fourier series coefficients of a square pulse

11.21 `fourier_complete_negative_half_plane`

11.22 `fourier_cubic_interaction_coefficients`

11.23 `fourier_derivative`

derivative via fourier transform
exponential convergence for periodic functions
results in spurious oscillations for aperiodic functions

input:

x : data, sampled in equal intervals

k : order of the derivative

dx : kth-derivative of x

note : 1) the derivative converges with spectral accuracy, i.e. is
exact up to rounding condition for L sufficiently large
and x being periodic
2) the derivative converges with order p, when x has only
p-continuous derivatives, including discontinuous
derivatives
over the boundary
3) discontinuous derivatives result in gibbs phenomenon

11.24 `fourier_derivative_matrix_1d`

11.25 `fourier_derivative_matrix_2d`

11.26 `fourier_expand`

expand values of fourier series

11.27 `fourier_fit`

fit a fourier series to a set of sample points that are not spaced
in
equal intervals

11.28 `fourier_freq2ind`

11.29 `fourier_interpolate`

interpolate samples `y` sampled at moments (location) `t` to locations
`ti`

11.30 `fourier_matrix`

transformation matrix for a continuous fourier series
(not for the discrete dft/fft)

11.31 `fourier_matrix2`

transformation matrix for a continuous fourier series
(not for the discrete dft/fft)

11.32 `fourier_matrix3`

transformation matrix for the continuous fourier transform
this is a matrix with $(2*n+1)$ real columns

11.33 `fourier_matrix_exp`

transformation matrix for a continuous fourier series
(not for the discrete dft/fft)

11.34 `fourier_multiplicative_interaction_coefficients`

11.35 `fourier_power`

powers of a continuous fourier series in sin/cos form

powers of $a^p = (u_r + u_1 \sin(\omega t) + u_2 \sin(\omega t + \delta)) ^p$
phase of first component assumed 0

frequencies higher than 2ω ignored in input
frequencies higher than 3ω not computed

11.36 `fourier_power_exp`

powers of the continuous fourier series
 $a^p = (u_r + u_1 \sin(\omega t) + u_2 \sin(\omega t + \delta)) ^p$
phase of first component assumed 0

higher orders than 2 ignored input
higher order than 3 not computed in output

$y = a_0 + \sum (a_j \sin(j\omega t) + b_j \cos(j\omega t))$
 $= \text{Real}(\sum_{i=0}^{\infty} c_i \exp(i\omega t)), c_i = a_i + b_i$

NOT the alternative $\sum_{i=-\infty}^{\infty} \tilde{c}_i$, tile $c_j = 1/2 a_j$
 $+ 1/2i b_j$

11.37 `fourier_predict`

expand a continous fourier series at times t

11.38 `fourier_quadratic_interaction_coefficients`

11.39 `fourier_random_phase_walk`

evalaute fourier series where the phase undergoes a brownian motion

11.40 `fourier_range`

approximate range of a continuous Fourier series with 2 components
`range(y) = max(y) - min(y)`

11.41 `fourier_regress`

fit a continuous Fourier series to a set of sample points not
sampled
at equal intervals

11.42 `fourier_resampled_fit`

fits coefficients of a continuous Fourier transform,
but stores them as resampled values

11.43 `fourier_resampled_predict`

interpolates a continuous Fourier series that has been stored as
values
at their support points

11.44 `fourier_series_signed_square`

coefficients of the Fourier series of $Q|Q|$
 $Q|Q| = Q_a^2 y$ (8.5)
 $= |\cos a + \cos t| (\cos a + \cos t)$ (8.6)
 $= a_0 + a_1 \cos t + \dots + a_n \cos n t$ (8.7)
 $\cos a$ is midrange
 $\cos t$ is tidal variation
c.f Dronkers 1964, eq. 8.10

11.45 `fourier_transform`

continuous Fourier transformation of y
(not discrete Fourier transformation `dft/fft`)

input:

```

b : data sampled at equal intervals
T : length of data in time or space, i.e. position of last
    sample if
        position of first sample is 0
T_max : maximum period to include

```

```

output :
  A : fourier matrix
  p : fourier transformation of b
  tt : TODO

```

11.46 `fourier_transform_fractional`

11.47 `fourier_truncate_negative_half_plane`

11.48 `hyperbolic_fourier_box`

11.49 `idftmtx_man`

inverse matrix for the discrete fourier transform in matlab style
 with a limited number of columns, thus ignoring higher frequencies
 keep $2nc+1$ columns (mean and conj-complex pairs of nc frequencies)

11.50 `laplace_2d_pwlinear`

solution to the Laplacian in two dimensions for a finite
 rectangular domain
 with piecewise constant boundary conditions
 linear system with 4 unknowns per frequency component
 these are coefficients of s, c, sh, ch

$$\begin{aligned}
 (pu*(s + c) + qu*(s' + c'))*(shu + chu) &= ru && \% \text{ upper bc} \\
 (pd*(s + c) + qd*(s' + c'))*(shd + chd) &= rd && \% \text{ lower bc} \\
 ((sl + cl)*(pl*(shl + chl) + ql*(shl' + chl'))) &= rl && \% \text{ left} \\
 &bc \\
 ((sr + cr)*(pr*(shr + chr) + qr*(shr' + chr'))) &= rr && \% \text{ right} \\
 &bc
 \end{aligned}$$

least squares with piecewise integration
[x0,p,q,r] piecewise linear polynomials at the boundaries

11.51 mean_fourier_power

11.52 moments_fourier_power

11.53 nanfft

discrete fourier transform of a data series with gaps

11.54 peaks

peaks of the power spectrum of a discrete fourier transform

rule for peaks: there is no higher value left or right of the "peak"

until the signal drops to $p \cdot y_{\text{peak}}$, $p = 0.5$

works best, when spectrum has been smoothened

input :

f : frequency

y : absolute value of fourier transform (power spectrum)

L : length in space or time of series

output :

a0 : amplitude

s0 : standard deviation (error?) of amplitude

w0 : width of peak

lambda = wave length (period?)

pdx : index of peak

f : frequency (if not given as input)

11.55 roots_fourier

zeros of continuous fourier series series

$$f = a_0 + \sum_{j=1}^n a_j \cos(j x) + b_j \sin(j x)$$

11.56 spectral_density

spectral density

11.57 std_fourier_power

11.58 test_complex_exp_product

11.59 test_fourier_filter

11.60 test_idftmtx

11.61 var_fourier_power

12 mathematics

mathematical functions of various kind

12.1 gaussfit_quantile

13 geometry/@Geometry

13.1 Geometry

13.2 arclength

arc length of a two dimensional curve

8th order accurate

does not require the segments length to vary smoothly

note: the curve can be considered parametric, e.g. $x = x(t)$, $y = y(t)$
and

and $t = t(s)$, but the error term contains derivatives of t ,
thus a non smooth t (strongly varying distance between points)
requires the scaling as done below

13.3 arclength_old

arc length of a two dimensional function

13.4 arclength_old2

arc length of a two dimensional function

13.5 base_point

base point (fusspunkt), i.e. point on a line with shortest distance
to another point

13.6 base_point_limited

base point (Fusspunkt) of a point on a line

13.7 centroid

centroid of a polygone

13.8 cosa_min_max

13.9 cross2

cross product in two dimensions

13.10 curvature

curvature of a function in two dimensions

13.11 ddot

sum of squares of cos of inner angles of triangle

13.12 distance

equclidan distance between two points

13.13 distance2

euclidean distance between two points
this function requires a and be of equal dimensions, or the least
the first pair or second pair to be a scalar

13.14 dot

dot product

13.15 edge_length

edge length

13.16 enclosed_angle

angle enclosed between two lines

13.17 enclosing_triangle

smallest enclosing equilateral triangle with bottom side parallel to
X axis

13.18 hexagon

coordinates of a hexagon, scaled and rotated

13.19 inPolygon

flag points contained in a polygon
much faster than matlab internal function

13.20 inTetra

flag points contained in tetrahedron

13.21 inTetra2

flag points contained in tetrahedron

13.22 inTriangle

flag points contained in triangle
function [flag, c] = inTriangle(P1,P2,P3,P0)

13.23 intersect

intersect between two lines

13.24 lineintersect

intersect of two lines

13.25 lineintersect1

intersect of two lines

13.26 minimum_distance_lines

minimum distance of two lines in three dimensions

13.27 mittenpunkt

mittenpunkt of a triangle

13.28 nagelpoint

nagelpoint of a triangle

13.29 onLine

13.30 orthocentre

orthocentre of triangle

13.31 `plumb_line`

13.32 `poly_area`

area of a polygon
function A = poly_area(x,y)

13.33 `poly_edges`

edges of a polygon

13.34 `poly_set`

associate point at arbitrary location with a polygon it is contained
in
and assign the value of the polygon to it

13.35 `poly_width`

width of polygon width holes by surface normals
holes / islands separated with NaN
order of points of outer boundary must be cw
order of points of holes must be ccw
note that this function does not give the true width for expanding
sections
use voronoi polygons for this

13.36 `polyxpoly`

intersections of two polygons

13.37 `project_to_curve`

closest point on a curve with respect to a point at distance to the
curve

13.38 quad_isconvex

13.39 random_disk

draw random points on the unit disk

13.40 random_simplex

random point inside of a triangle

13.41 sphere_volume

volume of a sphere
function v = sphere_volume(r)

13.42 tetra_volume

volume of a tetrahedron

13.43 tobarycentric

cartesian to barycentric coordinates

13.44 tobarycentric1

cartesian to barycentric coordinates

13.45 tobarycentric2

cartesian to barycentric coordinates

13.46 tobarycentric3

cartesian to barycentric coordinates

13.47 tri_angle

cos of angles of a triangle

13.48 tri_area

angle of a triangle

13.49 tri_centroid

centroid of a triangle

13.50 tri_distance_opposit_midpoint

distance between corner of a triangle and its opposing mid-point

13.51 tri_edge_length

edge length of a triangle

13.52 tri_edge_midpoint

mid point of a triangle

13.53 tri_excircle

excircle of a triangle

13.54 tri_height

height of a triangle

13.55 tri_incircle

incircle of a triangle

13.56 tri_isacute

flag acute triangles

13.57 tri_isobtuse

flag obtuse triangles

13.58 tri_semiperimeter

semiperimeter of a triangle

13.59 tri_side_length

edge length of triangle

14 geometry

14.1 Polygon

Simple 2D polygon class

Polygon properties:

x - x coordinates of polygon

y - y coordinates of polygon

nnodes - number of nodes in the polygon

Polygon methods:

- in - checks whether given points lie inside, on the edge, or outside of the polygon
- area - returns the area of the polygon
- centerline - computes the centerline of the river
- iscw - check whether polygon is clockwise
- reverse - reverse the order of the polygon

14.2 bounding_box

bounding box of X

14.3 curvature_1d

curvature of a sampled parametric curve in two dimensions

14.4 cvt

centroidal voronoi tessellation

14.5 deg_to_frac

degree, minutes and seconds to fractions

14.6 ellipse

return points on an ellipse
n : number of points
ci : confidence interval, i.e. for 1 sigma

14.7 ellipseX

x-coordinates of y-coordinates of an ellipse

14.8 ellipseY

14.9 first_intersect

get first intersection between lines in A and B

14.10 golden_ratio

golden ratio

14.11 hypot3

hypothenuse in 3D

14.12 meanangle

weighted mean of angles

14.13 meanangle2

mean angle

14.14 meanangle3

mean angle

14.15 meanangle4

mean angle

14.16 medianangle

median angle
angle, that has the smallest squared distance to all others

14.17 medianangle2

median angle

input
alpha : x*m, [rad] angle

ouput
ma : 1*m, [rad] median angle
sa : 1*m, [rad] standard error of median angle for uncorrelated
error

14.18 pilim

limit to +- pi

14.19 streamline_radius_of_curvature

streamline radius of curvature
simplifies when rotatate to streamwise coordinates to $R = 1/dv/ds * u$

15 histogram/@Histogram

15.1 2x

15.2 Histogram

15.3 bimodes

15.4 cdf

15.5 cdfS

15.6 chi2test

15.7 cmoment

15.8 cmomentS

15.9 entropy

15.10 entropyS

15.11 export_csv

15.12 iquantile

15.13 kstest

15.14 kurtosis

15.15 kurtosisS

15.16 mean

15.17 meanS

15.18 median

15.19 medianS

15.20 mode

15.21 modeS

15.22 moment

15.23 momentS

15.24 pdf

15.25 quantile

15.26 quantileS

15.27 resample

15.28 setup

15.29 skewness

15.30 skewnessS

15.31 stairs

15.32 stairsS

15.33 std

15.34 stdS

15.35 var

15.36 varS

16 histogram

16.1 hist_man

16.2 histadapt

16.3 histconst

16.4 pdf_poly

16.5 plotcdf

16.6 test_histogram

17 mathematics

mathematical functions of various kind

17.1 imrotmat

18 linear-algebra

18.1 averaging_matrix_2

18.2 colnorm

norms of columns

18.3 condest_

estimation of the condition number

18.4 connectivity_matrix

19 linear-algebra/coordinate-transformation

19.1 barycentric2cartesian

barycentric to cartesian coordinates

19.2 barycentric2cartesian3

convert barycentric to cartesian coordinates

19.3 cartesian2barycentric

cartesian to barycentric coordinates

19.4 cartesian_to_unit_triangle_basis

transform coordinates into unit triangle

19.5 ellipsoid2geoid

19.6 example_approximate_utm_conversion

19.7 latlon2utm

transform latitude and longitude to WGS84 UTM

19.8 latlon2utm_simple

19.9 lowrance_mercator_to_wgs84

convert lowrance coordinates to wgs84

based on spreadsheet by D Whitney King and Patty B at Lowrance

19.10 nmea2utm

convert nmea messages to utm coordinates

19.11 sn2xy

convert sn to xy coordinates

19.12 unit_triangle_to_cartesian

transform coordinates in unit triangle to cartesian coordinates

19.13 utm2latlon

convert wgs84 utm to latitude and longitude

19.14 xy2nt

project all points onto the cross section and assign them nz-coordinates

transform coordinate into N-T reference
rotate coordinate, so that cross section goes along x-axis
then x and y are n and t respectively scaled by width
N and T coordinates

19.15 xy2sn

convert cartesian to streamwise coordiantes

19.16 xy2sn.java

use java port for speed up

19.17 xy2sn_old

transform points from cartesian into streamwise coordinates

NOTE : prefer the java version, this has some problems with round off

20 linear-algebra

20.1 det2x2

2x2 matrix inverse of 2x2 matrices stacked along dim 3

20.2 det3x3

determinant of stacked 3x3 matrices

20.3 det4x4

determinant of stacked 4x4 matrices

20.4 diag2x2

diagonal of stacked 2x2 matrices

20.5 down

20.6 eig2x2

eigenvalues of stacked 2x2 matrices

21 linear-algebra/eigenvalue

21.1 eig_bisection

21.2 eig_inverse

21.3 eig_inverse_iteration

21.4 eig_power_iteration

22 linear-algebra/eigenvalue/jacobi-davidson

22.1 afun_jdm

22.2 davidson

22.3 jacobi_davidson

22.4 jacobi_davidson_qr

22.5 jacobi_davidson_qz

22.6 jacobi_davidson_simple

22.7 jdqr

```
% Read/set parameters
% Initiate global variables
% Return if eigenvalueproblem is trivial
% Initialize V, W:
%   V,W orthonormal, A*V=W*R+Qschur*E, R upper triangular
% The JD loop (Standard)
%   V orthogonal, V orthogonal to Qschur
%   V*V=eye(j), Qschur'*V=0,
%   W=A*V, M=V'*W
%
% Compute approximate eigenpair and residual
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
%
%
%
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Check for convergence
% Expand the partial Schur form
  Rschur=[Rschur;zeros(1,k)],Qschur'*MV(u)]; k=k+1;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Expand preconditioned Schur matrix PinvQ
% Check for shrinking the search subspace
% Solve correction equation
% Expand the subspaces of the interaction matrix
% The JD loop (Harmonic Ritz values)
%   Both V and W orthonormal and orthogonal w.r.t. Qschur
%   V*V=eye(j), Qschur'*V=0, W'*W=eye(j), Qschur'*W=0
%   (A*V-tau*V)=W*R+Qschur*E, E=Qschur'*(A*V-tau*V), M=W'*V
%
% Compute approximate eigenpair and residual
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
%
%
%
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

```

% Check for convergence
% Expand the partial Schur form
Rschur=[Rschur;zeros(1,k)],Qschur'*MV(u)]; k=k+1;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Expand preconditioned Schur matrix PinvQ
% Check for shrinking the search subspace
% Solve correction equation
% Expand the subspaces of the interaction matrix
% The JD loop (Harmonic Ritz values)
%   V W AV.
%   Both V and W orthonormal and orthogonal w.r.t. Qschur, AV=A*V-
%   tau*V
%   V*V=eye(j), W'*W=eye(j), Qschur'*V=0, Qschur'*W=0,
%   (I-Qschur*Qschur')*AV=W*R, M=W'*V; R=W'*AV;
%
% Compute approximate eigenpair and residual
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
%
%
%
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Check for convergence
% Expand the partial Schur form
Rschur=[Rschur;zeros(1,k)],Qschur'*MV(u)]; k=k+1;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Expand preconditioned Schur matrix PinvQ
% Check for shrinking the search subspace
% Solve correction equation
% Expand the subspaces of the interaction matrix
% The JD loop (Harmonic Ritz values)
%   W orthonormal, V and W orthogonal to Qschur,
%   W'*W=eye(j), Qschur'*V=0, Qschur'*W=0
%   W=(A*V-tau*V)-Qschur*E, E=Qschur'*(A*V-tau*V),
%   M=W'*V
% Compute approximate eigenpair and residual
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
%
%
%
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Check for convergence

```

```

% Expand the partial Schur form
Rschur=[Rschur;zeros(1,k)],Qschur'*MV(u)]; k=k+1;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Expand preconditioned Schur matrix PinvQ
% Check for shrinking the search subspace
% Solve correction equation
% Expand the subspaces of the interaction matrix
W=V*Q; V=V(:,1:j)/R; E=E/R; R=eye(j); M=Q(1:j,:)' /R;
W=V*H; V(:,j+1)=[];R=R'*R; M=H(1:j,:)' ;
%===== ARNOLDI (for initializing spaces)
=====
%===== END ARNOLDI
=====

% not accurate enough M=Rw'\(M/Rv);
%===== COMPUTE SORTED JORDAN FORM
=====

% compute vectors and matrices for skew projection
% solve preconditioned system
% 0 step of bicgstab eq. 1 step of bicgstab
% Then x is a multiple of b
% HIST=[0,1];
% explicit preconditioning
% compute norm in l-space
% HIST=[HIST;[nmv,rnorm/snorm]];
% sufficient accuracy. No need to update r,u
% implicit preconditioning
% collect the updates for x in l-space
% but, do the orth to Q implicitly
% compute norm in l-space
% HIST=[HIST;[nmv,rnorm/snorm]];
% sufficient accuracy. No need to update r,u
% Do the orth to Q explicitly
% In exact arithmetic not needed, but
% appears to be more stable.
% plot(HIST(:,1),log10(HIST(:,2)+eps),'*'), drawnow, pause
% 0 step of gmres eq. 1 step of gmres
% Then x is a multiple of b
%=====

% 0 step of gmres eq. 1 step of gmres
% Then x is a multiple of b
HIST=1;
% Lucky break-down
HIST=[HIST;(gamma~=0)/sqrt(rho)];
% Lucky break-down
% solve in least square sense
HIST=log10(HIST+eps); J=[0:size(HIST,1)-1]';

```

```

plot(J,HIST(:,1),'*'); drawnow,% pause
r=r/rho; rho=1;
% HIST=rho;
% HIST=[HIST;rho];
HIST=log10(HIST+eps); J=[0:size(HIST,1)-1]';
plot(J,HIST(:,1),'*'); drawnow,% pause
% HIST = rho;
% HIST=[HIST;rho];
HIST=log10(HIST+eps); J=[0:size(HIST,1)-1]';
plot(J,HIST(:,1),'*'); drawnow, pause
% HIST = rho;
% HIST=[HIST;rho];
HIST=log10(HIST+eps); J=[0:size(HIST,1)-1]';
plot(J,HIST(:,1),'*'); drawnow, pause
%----- compute schur form -----
A*Q=Q*S, Q'*Q=eye(size(A));
% transform real schur form to complex schur form
%----- find order eigenvalues -----
%----- reorder schur form -----
%----- compute qz form -----
%----- sort eigenvalues -----
%----- sort qz form -----
% i>j, move ith eigenvalue to position j
% determine dimension
% defaults
%% 'v'

```

22.8 jdqr sleipen

```

% Read/set parameters
% Initiate global variables
% Return if eigenvalueproblem is trivial
% Initialize V, W:
%   V,W orthonormal, A*V=W*R+Qschur*E, R upper triangular
% The JD loop (Standard)
%   V orthogonal, V orthogonal to Qschur
%   V*V=eye(j), Qschur'*V=0,
%   W=A*V, M=V'*W
%
% Compute approximate eigenpair and residual
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
%
%
%
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

```

```

% Check for convergence
% Expand the partial Schur form
  Rschur=[Rschur;zeros(1,k)],Qschur'*MV(u)]; k=k+1;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Expand preconditioned Schur matrix PinvQ
% Check for shrinking the search subspace
% Solve correction equation
% Expand the subspaces of the interaction matrix
% The JD loop (Harmonic Ritz values)
%   Both V and W orthonormal and orthogonal w.r.t. Qschur
%   V*V=eye(j), Qschur'*V=0, W'*W=eye(j), Qschur'*W=0
%   (A*V-tau*V)=W*R+Qschur*E, E=Qschur'*(A*V-tau*V), M=W'*V
%
% Compute approximate eigenpair and residual
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
%
%
%
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Check for convergence
% Expand the partial Schur form
  Rschur=[Rschur;zeros(1,k)],Qschur'*MV(u)]; k=k+1;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Expand preconditioned Schur matrix PinvQ
% Check for shrinking the search subspace
% Solve correction equation
% Expand the subspaces of the interaction matrix
% The JD loop (Harmonic Ritz values)
%   V W AV.
%   Both V and W orthonormal and orthogonal w.r.t. Qschur, AV=A*V-
%   tau*V
%   V*V=eye(j), W'*W=eye(j), Qschur'*V=0, Qschur'*W=0,
%   (I-Qschur*Qschur')*AV=W*R, M=W'*V; R=W'*AV;
%
% Compute approximate eigenpair and residual
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
%
%
%
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Check for convergence

```

```

% Expand the partial Schur form
Rschur=[Rschur;zeros(1,k)],Qschur'*MV(u)]; k=k+1;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Expand preconditioned Schur matrix PinvQ
% Check for shrinking the search subspace
% Solve correction equation
% Expand the subspaces of the interaction matrix
% The JD loop (Harmonic Ritz values)
%   W orthonormal, V and W orthogonal to Qschur,
%   W'*W=eye(j), Qschur'*V=0, Qschur'*W=0
%   W=(A*V-tau*V)-Qschur*E, E=Qschur'*(A*V-tau*V),
%   M=W'*V
% Compute approximate eigenpair and residual
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
%
%
%
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Check for convergence
% Expand the partial Schur form
Rschur=[Rschur;zeros(1,k)],Qschur'*MV(u)]; k=k+1;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Expand preconditioned Schur matrix PinvQ
% Check for shrinking the search subspace
% Solve correction equation
% Expand the subspaces of the interaction matrix
W=V*Q; V=V(:,1:j)/R; E=E/R; R=eye(j); M=Q(1:j,:)' /R;
W=V*H; V(:,j+1)=[];R=R'*R; M=H(1:j,:)' ;
%===== ARNOLDI (for initializing spaces)
=====
%===== END ARNOLDI
=====
% not accurate enough M=Rw'\(M/Rv);
%===== COMPUTE SORTED JORDAN FORM
=====
% compute vectors and matrices for skew projection
% solve preconditioned system
% 0 step of bicgstab eq. 1 step of bicgstab
% Then x is a multiple of b
% HIST=[0,1];
% explicit preconditioning
% compute norm in l-space
% HIST=[HIST;[nmv,rnorm/snorm]];

```

```

% sufficient accuracy. No need to update r,u
% implicit preconditioning
% collect the updates for x in l-space
% but, do the orth to Q implicitly
% compute norm in l-space
% HIST=[HIST;[nmv,rnorm/snorm]];
% sufficient accuracy. No need to update r,u
% Do the orth to Q explicitly
% In exact arithmetic not needed, but
% appears to be more stable.
% plot(HIST(:,1),log10(HIST(:,2)+eps),'*'), drawnow, pause
% 0 step of gmres eq. 1 step of gmres
% Then x is a multiple of b
%=====

% 0 step of gmres eq. 1 step of gmres
% Then x is a multiple of b
HIST=1;
% Lucky break-down
HIST=[HIST;(gamma~=0)/sqrt(rho)];
% Lucky break-down
% solve in least square sense
HIST=log10(HIST+eps); J=[0:size(HIST,1)-1]';
plot(J,HIST(:,1),'*'); drawnow,% pause
r=r/rho; rho=1;
% HIST=rho;
% HIST=[HIST;rho];
HIST=log10(HIST+eps); J=[0:size(HIST,1)-1]';
plot(J,HIST(:,1),'*'); drawnow,% pause
% HIST = rho;
% HIST=[HIST;rho];
HIST=log10(HIST+eps); J=[0:size(HIST,1)-1]';
plot(J,HIST(:,1),'*'); drawnow, pause
% HIST = rho;
% HIST=[HIST;rho];
HIST=log10(HIST+eps); J=[0:size(HIST,1)-1]';
plot(J,HIST(:,1),'*'); drawnow, pause
%----- compute schur form -----
A*Q=Q*S, Q'*Q=eye(size(A));
% transform real schur form to complex schur form
%----- find order eigenvalues -----
%----- reorder schur form -----
%----- compute qz form -----
%----- sort eigenvalues -----
%----- sort qz form -----
% i>j, move ith eigenvalue to position j
% determine dimension
% defaults
%% 'v'

```


22.9 jdqr_vorst

```
% Read/set parameters
% Initiate global variables
% Return if eigenvalueproblem is trivial
% Initialize V, W:
%   V,W orthonormal,  $A*V=W*R+Qschur*E$ , R upper triangular
% The JD loop (Standard)
%   V orthogonal, V orthogonal to Qschur
%    $V*V=eye(j)$ ,  $Qschur'*V=0$ ,
%    $W=A*V$ ,  $M=W'*W$ 
%
% Compute approximate eigenpair and residual
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
%
%
%
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Check for convergence
% Expand the partial Schur form
  Rschur=[Rschur;zeros(1,k)],Qschur'*MV(u)]; k=k+1;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Expand preconditioned Schur matrix PinvQ
% Check for shrinking the search subspace
% Solve correction equation
% Expand the subspaces of the interaction matrix
% The JD loop (Harmonic Ritz values)
%   Both V and W orthonormal and orthogonal w.r.t. Qschur
%    $V*V=eye(j)$ ,  $Qschur'*V=0$ ,  $W'*W=eye(j)$ ,  $Qschur'*W=0$ 
%    $(A*V-tau*V)=W*R+Qschur*E$ ,  $E=Qschur'*(A*V-tau*V)$ ,  $M=W'*V$ 
%
% Compute approximate eigenpair and residual
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
%
%
%
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Check for convergence
% Expand the partial Schur form
  Rschur=[Rschur;zeros(1,k)],Qschur'*MV(u)]; k=k+1;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

```

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Expand preconditioned Schur matrix PinvQ
% Check for shrinking the search subspace
% Solve correction equation
% Expand the subspaces of the interaction matrix
% The JD loop (Harmonic Ritz values)
%   V W AV.
%   Both V and W orthonormal and orthogonal w.r.t. Qschur, AV=A*V-
%   tau*V
%   V*V=eye(j), W'*W=eye(j), Qschur'*V=0, Qschur'*W=0,
%   (I-Qschur*Qschur')*AV=W*R, M=W'*V; R=W'*AV;
%
% Compute approximate eigenpair and residual
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
%
%
%
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Check for convergence
% Expand the partial Schur form
%   Rschur=[Rschur;zeros(1,k)],Qschur'*MV(u)]; k=k+1;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Expand preconditioned Schur matrix PinvQ
% Check for shrinking the search subspace
% Solve correction equation
% Expand the subspaces of the interaction matrix
% The JD loop (Harmonic Ritz values)
%   W orthonormal, V and W orthogonal to Qschur,
%   W'*W=eye(j), Qschur'*V=0, Qschur'*W=0
%   W=(A*V-tau*V)-Qschur*E, E=Qschur'*(A*V-tau*V),
%   M=W'*V
% Compute approximate eigenpair and residual
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
%
%
%
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Check for convergence
% Expand the partial Schur form
%   Rschur=[Rschur;zeros(1,k)],Qschur'*MV(u)]; k=k+1;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

```

```

% Expand preconditioned Schur matrix PinvQ
% Check for shrinking the search subspace
% Solve correction equation
% Expand the subspaces of the interaction matrix
W=V*Q; V=V(:,1:j)/R; E=E/R; R=eye(j); M=Q(1:j,:)' /R;
W=V*H; V(:,j+1)=[];R=R'*R; M=H(1:j,:)' ;
%===== ARNOLDI (for initializing spaces)
=====
%===== END ARNOLDI
=====
% not accurate enough M=Rw'\(M/Rv);
%===== COMPUTE SORTED JORDAN FORM
=====
% accepted separation between eigenvalues:
% no preconditioning
% solve left preconditioned system
% compute vectors and matrices for skew projection
% precondition and project r
% solve preconditioned system
% no preconditioning
% solve two-sided expl. preconditioned system
% compute vectors and matrices for skew projection
% precondition and project r
% solve preconditioned system
% "unprecondition" solution
%%% u(:,j+1)=Atilde*u(:,j)
%%% r(:,j+1)=Atilde*r(:,j)
%----- compute schur form -----
A*Q=Q*S, Q'*Q=eye(size(A));
% transform real schur form to complex schur form
%----- find order eigenvalues -----
%----- reorder schur form -----
%----- compute qz form -----
%----- sort eigenvalues -----
%----- sort qz form -----
% i>j, move ith eigenvalue to position j
% determine dimension
% defaults

```

22.10 jdqz

```

% Read/set parameters
% Return if eigenvalueproblem is trivial
% Initialize target, test space and interaction matrices
% V=RepGS(Qschur,V); [AV,BV]=MV(V); %%% more stability??
% W=RepGS(Zschur,eval(testspace)); %%% dangerous if sigma~lambda
% Solve the preconditioned correction equation

```

```

% Expand the subspaces and the interaction matrices
% Check for stagnation
% Solve projected eigenproblem
% Compute approximate eigenpair and residual
%=== an alternative, but less stable way of computing z =====
% display history
% save history
% check convergence
% EXPAND Schur form
% Expand preconditioned Schur matrix MinvZ=M\Zschur
% check for conjugate pair
% To detect whether another eigenpair is accurate enough
% restart if dim(V)> jmax
% Initialize target, test space and interaction matrices
% additional stabilisation. May not be needed
% V=RepGS(Zschur,V); [AV,BV]=MV(V);
% end add. stab.
% Solve the preconditioned correction equation
% expand the subspaces and the interaction matrices
% Check for stagnation
% compute approximate eigenpair
% Compute approximate eigenpair and residual
% display history
% save history
% check convergence
% expand Schur form
% ZastQ=Z'*Q0
% the final Qschur
% check for conjugate pair
% t perp Zschur, t in span(Q0,imag(q))
% To detect whether another eigenpair is accurate enough
% restart if dim(V)> jmax
%===== END JDQZ
=====
%=====
%===== PREPROCESSING
=====
%=====
%===== ARNOLDI (for initial spaces)
=====
%% then precondition=I and target = 0: apply Arnoldi with A
%===== END ARNOLDI
=====
%=====
%===== POSTPROCESSING
=====

```

```

%=====

%===== SORT QZ DECOMPOSITION INTERACTION MATRICES
%=====
%===== COMPUTE SORTED JORDAN FORM
%=====
%===== END JORDAN FORM
%=====
%===== OUTPUT
%=====

%===== UPDATE PRECONDITIONED SCHUR VECTORS
%=====

%=====

%===== SOLVE CORRECTION EQUATION
%=====

% solve preconditioned system
%=====

%===== LINEAR SOLVERS
%=====

% [At,Bt]=MV(x); At=theta(2)*At-theta(1)*Bt;
% xtol=norm(r-At+Z*(Z'*At))/norm(r);
%===== Iterative methods
%=====

% 0 step of bicgstab eq. 1 step of bicgstab
% Then x is a multiple of b
% HIST=[0,1];
% explicit preconditioning
% compute norm in l-space
% HIST=[HIST;[nmv,rnorm/snorm]];
% sufficient accuracy. No need to update r,u
% implicit preconditioning
% collect the updates for x in l-space
% but, do the orth to Z implicitly
% compute norm in l-space
% HIST=[HIST;[nmv,rnorm/snorm]];
% sufficient accuracy. No need to update r,u
% Do the orth to Z explicitly
% In exact arithmetic not needed, but
% appears to be more stable.

```

```

% plot(HIST(:,1),log10(HIST(:,2)+eps),'*'), drawnow
% 0 step of gmres eq. 1 step of gmres
% Then x is a multiple of b
%=====

% 0 step of gmres eq. 1 step of gmres
% Then x is a multiple of b
HIST=1;
% Lucky break-down
HIST=[HIST;(gamma~=0)/sqrt(rho)];
% Lucky break-down
% solve in least square sense
HIST=log10(HIST+eps); J=[0:size(HIST,1)-1]';
plot(J,HIST(:,1),'*'); drawnow
%===== END SOLVE CORRECTION EQUATION
=====
%=====

%===== BASIC OPERATIONS
=====
%=====

y(1:5,1), pause
%===== COMPUTE r AND z
=====
% E*u=Q*sigma, sigma(1,1)>sigma(2,2)
%===== END computation r and z
=====
%=====

%===== Orthogonalisation
=====
%=====

%===== END Orthogonalisation
=====
%=====

%===== Sorts Schur form
=====
%=====

kappa=max(norm(A,inf)/max(norm(B,inf),1.e-12),1);
kappa=2^(round(log2(kappa)));
%----- compute the qz factorization -----
%----- scale the eigenvalues -----
%----- sort the eigenvalues -----
%----- swap the qz form -----
% repeat SwapQZ if angle is too small

```

```

%=====

%=====

% i>j, move ith eigenvalue to position j
% compute q s.t. C*q=(t(i,1)*S-s(i,1)*T)*q=0
C*P=Q*R
check whether last but one diag. elt r nonzero
C*q
% end computation q
%===== END sort QZ decomposition interaction matrices
=====
%=====

%===== INITIALIZATION
=====
%=====

%=====

% defaults          %%%% search for 'xx' in fieldnames
%% 'ma'
%% 'sch'
%% 'to'
%% 'di'
% jmin=nselect+p0 %%%% 'jmi'
% jmax=jmin+p1 %%%% 'jma'
%% 'te'
%% 'pai'
%% 'av'
%% 'tr'
%% 'fix'
%% 'ns'
%% 'ch'
%% 'lso'
%% 'ls_m'
%% 'ls_t'
%% 'ls_e'
%% 'ty'
%% 'l_'
%% 'u_'
%% 'p_'
%% 'sca'
%% 'v0'
initiation
'standard'
'harmonic'
'searchspace'

```

```
%=====
% or Operator_Form=3 or Operator_Form=5???
%=====

%===== DISPLAY FUNCTIONS
%=====
%=====
%=====
%=====
%=====
```

22.11 mfunc_jdm

22.12 mgs

22.13 minres_

22.14 mv_jacobi_davidson

23 linear-algebra

23.1 first

23.2 gershgorin_circle

range of eigenvalues determined by the gershgorin circle theorem

23.3 haussdorff

haussdorf dimension

box counting: count rectangles passed through by line (covered by polygon)

Koch snow flake 3:4 -> 1.2619

Kantor set 2:3, (4:9) -> 0.6309

quadrat 4:2, 9:3, 16:4 -> 2

23.4 eig2x2

reconstruct matrix from eigenvalue decomposition

23.5 inv2x2

2x2 inverse of stacked matrices

23.6 inv3x3

23.7 inv4x4

inverse of stacked 4x4 matrices

23.8 kernel2matrix

24 linear-algebra/lanczos

24.1 arnoldi

24.2 `arnoldi_new`

24.3 `eigs_lanczos_man`

24.4 `lanczos`

24.5 `lanczos_`

24.6 `lanczos_biorthogonal`

24.7 `lanczos_biorthogonal_improved`

24.8 `lanczos_ghep`

24.9 `mv_lanczos`

24.10 `reorthogonalise`

24.11 `test_lanczos`

25 linear-algebra

25.1 laplacian_eigenvalue

25.2 laplacian_eigenvector

25.3 laplacian_power

25.4 least_squares_perpendicular_offset

25.5 left

left element of vector, leftmost column is extrapolated

26 linear-algebra/linear-systems

26.1 gmres_man

break on convergence

26.2 minres_recycle

27 linear-algebra

27.1 lpmean

mean of pth-power of a

27.2 `lpnorm`

norm of lth-power of a

27.3 `matvec3`

matrix-vector product of stacked matrices and vectors

27.4 `max2d`

maximum value and i-j index for matrix

27.5 `mid`

mid point between neighbouring vector elements

27.6 `mpoweri`

approximation of A^p , where p is not integer by quadratic interpolation

27.7 `mtimes2x2`

27.8 `mtimes3x3`

product of stacked 3x3 matrices

27.9 `nannorm`

norm of a vector, skips nan-values

27.10 nanshift

shift vector, but set out of range values to NaN

27.11 nl

number rows (lines) of a matrix

analogue to unix nl command

27.12 normalise

normalise a vector or the columns of a matrix

note that the columns are independently normalised, and hence not necessarily
orthogonal to each other use the gram schmidt algorithm for this (qr or orth)

27.13 normalize1

normalize columns in x to [-1,1]

27.14 normrows

27.15 orth2

make matrix A orthogonal to B

27.16 orth_man

orthogonalize the columns of A

27.17 orthogonalise

make x orthogonal to Y

27.18 padd2

padd values around a 2d (image) matrix, constant extrapolation

27.19 paddext

padd values to vactor
not suitable for noisy data
order = 0 : constant extrapolation (hold)
order = 1 : linear extrapolation

27.20 paddval1

padd values at end of x

27.21 paddval2

padd values to x

28 linear-algebra/polynomial

28.1 chebychev

c.f. Dronkers 1964, eq. 8.15, p. 300
chebycheff polynomials
function c = chebychev(x,n)

28.2 piecewise_polynomial

evaluate piecewise polynomial

28.3 roots1

roots of linear functions

28.4 roots2

roots of quadratic function
 $c_1 x^2 + c_2 x + c_3 = 0$

28.5 roots2poly

28.6 roots3

28.7 roots4

28.8 roots_piecewise_linear

28.9 test_roots4

28.10 vanderi_1d

vandermonde matrix of an integral

29 linear-algebra

29.1 randrot

random rotation matrix

29.2 right

get right column by shifting columns to left
extrapolate rightmost column

29.3 rot2

rotation matrix from angle

29.4 rot2dir

rotation matrix from direction vector

29.5 rot3

29.6 rotR

29.7 rownorm

29.8 simmilarity_matrix

29.9 spnorm

frobenius norm

29.10 spzeros

allocate a sparze matrix of zeros

29.11 test_roots3

29.12 transform_minmax

29.13 transpose3

transpose stacked 3x3 matrices

29.14 transposeall

29.15 up

29.16 vander_nd

29.17 vanderd_2d

30 logic

bitwise operations on integers

30.1 bitor_man

bitwise OR of the numbers of the columns of A

input:
A (positive integer)

31 master/plot

31.1 attach_boundary_value

31.2 cartesian_polar

31.3 img_vargrid

31.4 plot_basis_functions

31.5 plot_convergence

31.6 plot_dof

31.7 `plot_eigenbar`

31.8 `plot_error_estimation`

31.9 `plot_error_estimation_2`

31.10 `plot_error_fem`

31.11 `plot_fdm_kernel`

31.12 `plot_fdm_vs_fem`

31.13 `plot_fem_accuracy`

31.14 `plot_function_and_grid`

31.15 `plot_hat`

31.16 `plot_hydrogen_wf`

31.17 `plot_mesh`

31.18 `plot_mesh_2`

31.19 `plot_refine`

31.20 `plot_refine_3d`

31.21 `plot_runtime`

31.22 `plot_spectrum`

31.23 `plot_wavefunction`

32 `master/ported`

32.1 `assemble_2d_phi_phi`

32.2 `assemble_3d_dphi_dphi`

32.3 assemble_3d_phi_phi

32.4 dV_2d_

32.5 derivative_2d

32.6 derivative_3d

32.7 element_neighbour_2d

32.8 prefetch_2d_

32.9 promote_2d_3_10

32.10 promote_2d_3_15

32.11 promote_2d_3_21

32.12 promote_2d_3_6

32.13 `promote_3d_4_10`

32.14 `promote_3d_4_20`

32.15 `promote_3d_4_35`

32.16 `vander_2d`

32.17 `vander_3d`

33 mathematics

mathematical functions of various kind

33.1 `monotoneous_indices`

33.2 `nearest_fractional_timestep`

34 number-theory

34.1 `ceiln`

floor to leading n-digits

34.2 digitsb

number of digits with respect to specified base

34.3 floorn

floor to n-digits

34.4 iseven

true for even numbers in X

34.5 multichoosek

all combinations of length k from set values with repetitions
c.f. nchoosek, combinations without repetition

input :
 x : scalar integer or vector of arbitrary numbers
 k : length of subsets
output :
 if x scalar : number of combinations
 if x vector : the exact combinations

34.6 nchoosek_man

vectorised binomial coefficient
 $b = N!/K!(N-K)!$

34.7 pythagorean_triple

pythagorean triple

34.8 roundn

round to n digits

35 numerical-methods

35.1 advect_analytic

36 numerical-methods/differentiation

36.1 derivative1

first derivative on variable mesh
second order accurate

36.2 derivative2

second derivative on a variable mesh

37 numerical-methods

37.1 diffuse_analytic

38 numerical-methods/finite-difference

38.1 cdiff

differences of columns of X
degree = 1 : central first order differences
degree = 2 : central second order differences

38.2 cdiffb

differences of columns of X
degree = 1 : central first order differences
degree = 2 : central second order differences
TODO use difference matrix function for simplicity

38.3 central_difference

38.4 cmean

single gaussian smoothing step with kernel $1/4*[1,2,1]$

38.5 cmean2

38.6 derivative_matrix_1_1d

finite difference matrix of first derivative in one dimensions
n : number of grid points
h = L/(n+1) constant step with

```
function [D1, d1] = derivative_matrix_1d(n,L,order)
```

38.7 derivative_matrix_2_1d

finite derivative matrix of second derivative in one dimension

38.8 derivative_matrix_2d

finite difference derivative matrix in two dimensions

38.9 derivative_matrix_curvilinear

derivative matrix on a curvilinear grid

38.10 derivative_matrix_curvilinear_2

derivative matrix on a two dimensional curvilinear grid
the grid has not necessarily to be orthogonal

38.11 difference_kernel

difference kernels for equispaced grids
c.f. Computing the Spectrum of the Confined Hydrogen Atom, Kastner,
2012

38.12 diffusion_matrix_2d_anisotropic

38.13 diffusion_matrix_2d_anisotropic2

38.14 directional_neighbour

38.15 distmat

distance matrix for a 2 dimensional rectangular matrix

38.16 downwind_difference

38.17 gradpde2d

objective function gradiend on two dimensional regular grid
numeric gradient for non-linear least squares optimisation
of a PDE on a rectangular grid
 $x_* = \min(f(x))$
 $f = (v(x) - v(x_*))^2 = f(x) + A \, dx + O(dx^2)$
 $a_{ij} = df_i/dx_j$

38.18 laplacian

38.19 laplacian_fdm

finite difference matrix of the laplacian
BC

38.20 lrmean

mean of the left and right element

39 numerical-methods/finite-difference/master

39.1 fdm_adaptive_grid

39.2 fdm_adaptive_refinement_old

39.3 fdm_assemble_d1_2d

39.4 fdm_assemble_d2_2d

39.5 fdm_confinement

39.6 fdm_d_vargrid

39.7 fdm_h_unstructured

39.8 `fdm_hydrogen_vargrid`

39.9 `fdm_mark_unstructured_2d`

39.10 `fdm_plot`

39.11 `fdm_plot_series`

39.12 `fdm_refine_2d`

39.13 `fdm_refine_3d`

39.14 `fdm_refine_unstructured_2d`

39.15 `fdm_schroedinger_2d`

39.16 `fdm_schroedinger_3d`

39.17 `relocate`

40 numerical-methods/finite-difference

40.1 mid

mid point between neighbouring vector elements

40.2 pwmid

segment end point to segment mid point transformation for regular 1
d grids

40.3 ratio

ratio of two subsequent values

40.4 steplength

step length of a vector if it were equispaced

40.5 swapoddeven

swap odd and even elements in a vector

40.6 test_derivative_matrix_2d

40.7 test_derivative_matrix_curvilinear

40.8 test_difference_kernel

40.9 upwind_difference

41 numerical-methods/finite-element

41.1 Mesh_2d.java

41.2 Tree_2d.java

41.3 assemble_1d_dphi_dphi

41.4 assemble_1d_phi_phi

41.5 assemble_2d_dphi_dphi.java

41.6 assemble_2d_phi_phi.java

41.7 assemble_3d_dphi_dphi.java

41.8 assemble_3d_phi_phi.java

41.9 boundary_1d

41.10 boundary_2d

41.11 boundary_3d

41.12 check_area_2d

41.13 circmesh

41.14 cropradius

41.15 display_2d

41.16 display_3d

41.17 distort

41.18 err_2d

41.19 `estimate_err_2d_3`

41.20 `example_1d`

41.21 `example_2d`

41.22 `explode`

41.23 `fem_2d`

41.24 `fem_2d_heuristic_mesh`

41.25 `fem_get_2d_radial`

41.26 `fem_interpolation`

41.27 `fem_plot_1d`

41.28 `fem_plot_1d_series`

41.29 fem_plot_2d

41.30 fem_plot_2d_series

41.31 fem_plot_3d

41.32 fem_plot_3d_series

41.33 fem_plot_confine_series

41.34 fem_radial

adaptive grid
constant grid

41.35 flip_2d

41.36 get_mesh_arrays

41.37 hashkey

42 numerical-methods/finite-element/int

42.1 int_1d_equal

42.2 int_1d_equal_exp

42.3 int_1d_gauss

42.4 int_1d_gauss_1

```
w : weights
    2/(1-xi^2)(P'_n(xi))^2
b : baricentric coordinates
    ith-root of legendre polynomial of order n
second order, midpoint rule
function [w, b, flag] = int_1d_gauss_1()
```

42.5 int_1d_gauss_2

42.6 int_1d_gauss_3

42.7 int_1d_gauss_4

42.8 int_1d_gauss_5

42.9 `int_1d_gauss_6`

42.10 `int_1d_gauss_lobatto`

42.11 `int_1d_gauss_n`

42.12 `int_1d_nc_2`

42.13 `int_1d_nc_3`

42.14 `int_1d_nc_4`

42.15 `int_1d_nc_5`

42.16 `int_1d_nc_6`

42.17 `int_1d_nc_7`

42.18 `int_1d_nc_7_hardy`

42.19 int_2d_gauss_1

42.20 int_2d_gauss_12

42.21 int_2d_gauss_13

42.22 int_2d_gauss_16

42.23 int_2d_gauss_19

42.24 int_2d_gauss_25

42.25 int_2d_gauss_3

42.26 int_2d_gauss_33

42.27 int_2d_gauss_4

42.28 int_2d_gauss_6

42.29 int_2d_gauss_7

42.30 int_2d_gauss_9

42.31 int_2d_nc_10

42.32 int_2d_nc_15

42.33 int_2d_nc_21

42.34 int_2d_nc_3

42.35 int_2d_nc_6

42.36 int_3d_gauss_1

42.37 int_3d_gauss_11

42.38 int_3d_gauss_14

42.39 int_3d_gauss_15

42.40 int_3d_gauss_24

42.41 int_3d_gauss_4

42.42 int_3d_gauss_45

42.43 int_3d_gauss_5

42.44 int_3d_nc_11

42.45 int_3d_nc_4

42.46 int_3d_nc_6

42.47 int_3d_nc_8

43 numerical-methods/finite-element

43.1 interpolation_matrix

43.2 mark

43.3 mark_1d

43.4 mesh_1d_uniform

43.5 mesh_3d_uniform

43.6 mesh_interpolate

43.7 neighbour_1d

43.8 old

43.9 pdeeig_1d

43.10 pdeeig_2d

43.11 pdeeig_3d

43.12 polynomial_derivative_1d

43.13 potential_const

43.14 potential_coulomb

43.15 potential_harmonic_oscillator

43.16 project_circle

43.17 project_rectangle

43.18 promote_1d_2_3

43.19 promote_1d_2_4

43.20 promote_1d_2_5

43.21 promote_1d_2_6

43.22 quadrilaterate

43.23 recalculate_regularity_2d

43.24 refine_1d

43.25 refine_2d_21

43.26 refine_2d_structural

43.27 regularity_1d

43.28 regularity_2d

43.29 regularity_3d

```
{      T = [1 2 3 4];  
}
```

43.30 relocate_2d

43.31 test_circmesh

43.32 test_hermite

43.33 tri_assign_points

43.34 triangulation_uniform

43.35 vander_1d

van der Monde matrix

43.36 vanderd_1d

43.37 vanderi_1d

44 numerical-methods/finite-volume/@Advection

44.1 Advection

FVM treatment of the Advection equation

44.2 dot_advection

advection equation

45 numerical-methods/finite-volume/@Burgers

45.1 burgers_split

viscous Burgers' equation,
mixed analytic and numerical derivative in frequency space
by splitting scheme
 $u_t = -(0.5*u^2)_x + c*u_{xx}$

45.2 dot_burgers_fdm

viscous burgers' equation
 $u_t = -d/dx (1/2*u^2) + c d^2/dx^2 u_{xx}$

45.3 dot_burgers_fft

viscous Burgers' equation in frequency space
 $u_t + (0.5*u^2)_x = c*u_{xx}$

46 numerical-methods/finite-volume/@Finite_Volume

46.1 Finite_Volume

finite volume method for partial differential equations 1+1
dimensions
(time and space)

46.2 apply_bc

apply boundary conditions

46.3 solve

solve the the PDE by successively stepping in time
this is a trivial implmentation with constant step length
severity of diffusive error depends on dt/dx-ratio
stability depends on wave height
printf('Progress %2.1f%% %2.1fs\n',100*(t-Ti
(1))/(Ti(2)-Ti(1)),t_real);

46.4 step_split_strang

step in time, treat inhomogeneous part by Strang splitting
this scheme is not suitable for stationary solutions, for example
steady shallow water flow

46.5 step_unsplit

step in time, without splitting the inhomogeneous term

47 numerical-methods/finite-volume/@Flux_Limiter

47.1 Flux_Limiter

class of flux limiters

47.2 beam_warming

beam warming scheme
low resolution
note: works only if sign of eigenvalues point into the same
direction according to RL

47.3 fromm

fromme limiter
low res

47.4 lax_wendroff

lax wendroff scheme
second order accurate, but no tvd
this is effectively not a limiter
eq. 6.39 in randall, leveque

47.5 minmod

min-mod schock limiter

47.6 monotized_central

monotonized central flux limiter

47.7 muscl

muscl flux limiter

47.8 superbee

superbee limiter

47.9 upwind

godunov scheme
godunov, first order accurate

47.10 vanLeer

van Leer limiter

48 numerical-methods/finite-volume/@KDV

48.1 dot_kdv_fdm

korteweg de vries equation
 $u_t + (0.5*u^2)_x = c*u_{xxx}$

48.2 dot_kdv_fft

korteweg de vries equation
compute derivatives in frequency space
 $u_t + (0.5*u^2)_x = c*u_{xxx}$

48.3 kdv_split

korteweg de vries equation in frequency space,
derivative treated by splitting scheme

49 numerical-methods/finite-volume/@Reconstruct_Average_E

49.1 Reconstruct_Average_Evolve

Reconstruct Average Evolve Finite Volume Method for treatment of
1+1D pdes

McCronack Scheme

err = $O(dt^2) + O(dx^2)$, except as discontinuities

error:

```
h_xxx(3:end-2) = 1/dx^3*( -0.5*h(1:end-4) + h(2:end-3) - h(4:
    end-1) + 0.5*h(5:end) );
th = -1/6*dx^2*qh_.*(1 - (qh_*dt/dx).^2).*h_xxx;
```

49.2 advect_highres

single time step for the reconstruct evolve algorithm

49.3 advect_lowres

single time step
low resolution

50 numerical-methods/finite-volume

50.1 Godunov

Godunov, upwind method for systems of pdes

50.2 Lax_Friedrich

Lax-Friedrich-Method
for hyperbolic conservation laws
 $\text{err} = O(\Delta t) + O(\Delta x)$
 $|a \Delta t / \Delta x| < 1$

50.3 Measure

50.4 Roe

non linear roe solver for the SWE (randall, leveque 15.3.1)

The roe solver guarantess:

- A is diagonalisable with real eigenvalues (15.12)
- can be determined by a closed formula
- is an efficient replacement for true Rieman solver

50.5 fv_swe

wrapper for solving SWE

50.6 staggered_euler

forward euler method with staggered grid

50.7 staggered_grid

staggered grid approximation to the SWE

51 numerical-methods

51.1 grid2quad

extract rectangular elements of a structured grid
in form of an unstructured quad-mesh format

52 numerical-methods/integration

52.1 cumintL

cumulative integral from left to right

52.2 cumintR

cumulative integral from right to left

52.3 cumint_trapezoidal

integrate y along x with the trapezoidal rule

52.4 int_1d_gauss_laguerre

52.5 int_trapezoidal

integrate y along x with the trapezoidal rule

53 numerical-methods/interpolation/@Kriging

53.1 Kriging

class for Kriging interpolation

53.2 estimate_semivariance

estimate the parameter of the semivariance model for Kriging
interpolation
 % set up the regression matrix and solve for
 parameters

53.3 interpolate_

interpolate with Krieking method

this function may interpolate several quantities per coordinate,
using the same variogram, if the semivariance of the quantities
differs,
the user may prefer to estimate the semivariance and interpolate
each quantity
individually

Xs : source point coordinates
Vs : value at source points
Xt : targe point coordinates
Vt : value at target points
E2t : squared interpolation error at target points

54 numerical-methods/interpolation/@RegularizedInterpolator

54.1 RegularizedInterpolator1

class for regularized interpolation (Thikonov) on a 1D mesh

54.2 init

initialize the interpolator with a set of sampling points

55 numerical-methods/interpolation/@RegularizedInterpolator

55.1 RegularizedInterpolator2

class for regularized interpolation on an unstructures mesh (
interpolation)

55.2 init

initialize the interpolator with a set of point samples

56 numerical-methods/interpolation/@RegularizedInterpolator

56.1 RegularizedInterpolator3

class for regularized interpolation (Tikhonov) on a triangulation
(unstructured mesh)

56.2 init

initialize the interpolator with a set of sampling points

57 numerical-methods/interpolation

57.1 IDW

spatial averaging by inverse distance weighting

57.2 IPoly

polynomial interpolation class

57.3 IRBM

interpolate by the radial basis function method

```
fprintf(1,'Progress IRBM: %d%%\n',round(100*  
    idx/size(Xi,1)));
```

57.4 ISparse

sparse interpolation class

57.5 Inn

nearest neighbour interpolation

57.6 Interpolator

interpolator super-class

```
fprintf(1,'Progress: %f%% %fs\n',100*  
    idx/size(Xt,1),t);
```

57.7 fixnan

fill nan-values in vector with gaps

57.8 idw1

spatial average by inverse distance weighting

57.9 idw2

spatial average by inverse distance weighting

57.10 inner2outer

linear interpolation of segment mid point to grid points at segment
ends
assumes equal grid spacing

57.11 inner2outer2

interpolate from element (segment) centres to edge points

57.12 interp1_circular

57.13 interp1_limited

interpolate values, but not beyond a certain distance
this function is idempotent, i.e. it will not extrapolate over into
gaps
exceedint the limit and thus not spuriously extend the series when
called a second time on the same data

57.14 interp1_man

interpolate

57.15 `interp1_piecewise_linear`

57.16 `interp1_save`

make interpolation save to round off errors
the matlab internal interpolation suffers from rounding errors,
which
are unacceptable when values of X and Y are large (for example UTM
coordinates)
this normalization prevents this

57.17 `interp1_slope`

quadratic interpolation returning value and derivative(s)

57.18 `interp1_smooth`

57.19 `interp1_unique`

matlab fails to interpolate, when x values are not unique
this function makes the values unique before use

57.20 `interp2_man`

nearest neighbour interpolation in two dimensions

57.21 `interp_angle`

interpolate an angle

57.22 interp_fourier

interpolation by the fourier method

57.23 interp_fourier_batch

batch interpolation by the fourier interpolation

57.24 interp_sn

interpolate along streamwise coordinates
This gives similar result to setting aspect ratio for sN to
infinity,
but not quite, as the input point set is not dense (scale for sN to
infinity does not work)
 sdx = sdx(sdx_);

57.25 interp_sn2

interpolation in streamwise coordinates

57.26 interp_sn3

57.27 interp_sn_

57.28 limit_by_distance_1d

smooth subsequent values along a curve such that
 $v(x_0+dx) < v(x_0) + (ratio-1)*dx$
if v is the edge length in a resampled polygon, then $v_i/v_{(i+1)} <$
 ratio
 $ratio^1 = \exp(a*1)$

57.29 resample1

interpolation along a parametric curve with variable step width

57.30 resample_d_min

resample a function

57.31 resample_vector

resample a track so that velocity vectors do not run into each other

57.32 test_interp1_limited

58 numerical-methods

58.1 inverse_complex

58.2 maccormack_step

58.3 minmod

59 numerical-methods/multigrid

59.1 mg_interpolate

59.2 mg_restrict

60 numerical-methods/ode/@BVPS_Characteristic

60.1 BVPS_Characteristic

solve coupled first- and second-order 1D boundary-value problems

60.2 assemble1_A

assemble the discretisation matrix for a first order ode
(mean component, zero frequency)

60.3 assemble1_A_Q

assemble the discretisation matrix for a first order ode
(mean component, zero frequency)

60.4 assemble2_A

assemble the discretisation matrix for a second-order ode
(non-zero frequency component)

60.5 assemble_AA

assemble the discretisation matrix for each channel
iteratively calls assembly for each frequency components

60.6 assemble_AAA

assemble the discretisation matrix for the entire network
iteratively calls assembly for each channel

60.7 `assemble_Ic`

60.8 `bvp1c`

60.9 `check_arguments`

60.10 `couple_junctions`

60.11 `derivative`

60.12 `init`

60.13 `inner2outer_bvp2c`

60.14 `reconstruct`

60.15 `resample`

60.16 solve

solve system of non-linear second order odes (in more than one variable)
as boundary value problems

odefun provides ode coefficients c:

$$c(x,1) y''(x) + c(x,2) y'(x) + c(x,3) y = c(x,4) \\ c_1 y'' + c_2 y' + c_3 y + c_4 = c_4$$

subject to the boundary conditions

bcfun provides v and p and optionally q, so that:

$$b_1 y + b_2 y' = f$$

$$q(x,1)*(p(x,1) y_l(x) + p(x,2) y_l'(x) \\ + q(x,2)*(p(x,1) y_r(x) + p(x,2) y_r'(x) = v(x)$$

where q weighs the waves travelling from left to right and right to left (default [1 1])

60.17 test_assemble1_A

60.18 test_assemble2_A

61 numerical-methods/ode/@Time_Stepper

61.1 Time_Stepper

61.2 solve

62 numerical-methods/ode

62.1 bvp2fdm

solve system of non-linear second order odes (in more than one variable)
 as boundary value problems by the finite difference method

 odefun provides ode coefficients c:

$$c(x,1) y''(x) + c(x,2) y'(x) + c(x,3) y = c(x,4)$$

$$c_1 y'' + c_2 y' + c_3 y + c_4 = 0$$

 subject to the boundary conditions
 bcfun provides v and p and optionally q, so that:

$$b_1 y + b_2 y' = f$$

$$q(x,1)*(p(x,1) y_l(x) + p(x,2) y_l'(x) + q(x,2)*(p(x,1) y_r(x) + p(x,2) y_r'(x) = v(x)$$
 where q weighs the waves travelling from left to right and right to left (default [1 1])

62.2 bvp2wavetrain

solve second order boundary value problem by repeated integration

62.3 bvp2wavetwopass

two pass solution for the linearised wave equation
 solve first for the wave number k, and then for y

62.4 ivp_euler_forward

solve initial value problem by the euler forward method

62.5 ivp_euler_forward2

62.6 ivprk2

solve initial value problem by the two step runge kutta method

62.7 ode2_matrix

transformation matrix of second order ode
to left and right going wave

```
c = odefun(x)
c1 y'' + c2' y + c3 y == 0
y = y_p + y_m, left and right going wave
d/dx [y_p, y_m] = A*[y_m, y_p]
```

62.8 ode2characteristic

second order odes
transmitted and reflected wave

62.9 step_trapezoidal

single trapezoidal step

62.10 test_bvp2

63 numerical-methods/optimisation

63.1 aitken_iteration

63.2 anderson_iteration

63.3 armijo_stopping_criterion

armijo stopping criterion for optimizations

63.4 astar

astar path finding algorithm

63.5 binsearch

binary search on a line

63.6 bisection

bisection

63.7 box1

test objective function for optimisation routines

63.8 box2

63.9 cauchy

63.10 cauchy2

solve non-linear system by cuachy's method
slower than quadratic optimisation, but does not require a hessian
fun : objective function, returns
 f : scalar, objective function value
 g : nx1, gradient
x : nx1, initial position
opt : options

63.11 directional_derivative

directional (projected) derivative
d : derivative, highest first
p : series expansion around x0

63.12 dud

optimization by the dud algorithm

63.13 extreme3

extract maxima by quadratic approximation from sampled function val
(t)
intended to be called after [mval, mid] = max(val) for refinement
of
location and maximum

input
t : sampling time (uniformly spaced)
v : values at sampling times
output:
tdx : index where extremum should be computed
t0 : location of the extremum
val0 : value of extremum

$v'(dt0) = 0$ and $v''(dt0)$ determines type of extremum

63.14 extreme_quadratic

63.15 ftest

63.16 fzero_bisect

63.17 fzero_newton

63.18 grad

numerical gradient

63.19 hessian

numerical hessian

63.20 hessian_from_gradient

numerical hessian from gradient

63.21 hessian_projected

numerical hessian projected to one dimension

63.22 line_search

bisection routine

63.23 line_search2

bisection method

fun : objective funct
x0 : start value
f0 : objective function value at x0
g : gradient at x0
p : search direction from x0 (p = g for steepest descend)
h : initial step length (default 1)
lb : lower bound for x
up : upper bound for x

63.24 line_search_polynomial

```
polynomial line search
fun : objective funct
x0  : start value
f0  : objective function value at x0
g   : gradient at x0
dir : search direction from x0 (p = g for steepest descend)
h   : initial step length (default 1)
lb  : lower bound for x
up  : upper bound for x
```

63.25 line_search_polynomial2

```
cubic line search
fun : objective funct
x0  : start value
f0  : objective function value at x0
g   : gradient at x0
dir : search direction from x0 (p = g for steepest descend)
h   : initial step length (default 1)
lb  : lower bound for x
up  : upper bound for x
```

63.26 line_search_quadratic

```
quadratic line search
fun : objective funct
x0  : start value
f0  : objective function value at x0
g   : gradient at x0
dir : search direction from x0 (p = g for steepest descend)
h   : initial step length (default 1)
lb  : lower bound for x
up  : upper bound for x
```

63.27 line_search_quadratic2

```
quadratic line search
```


63.28 line_search_wolfe

line search by wolfe method
c.f.: OPTIMIZATION THEORY AND METHODS - Nonlinear Programming, Sun,
Yuan

63.29 ls_bgfs

least squares by the bgfs method

63.30 ls_broyden

least squares by the broyden method
for rectangular / non symmetric systems
Numerical Optimization nodedal
Practical Methods of Optimization fletcher
c.f. gerber 1981
c.f. fletcher 1978 (more advanced, not used here)
c.f. Kelley 1999 ch. 4

BGFS:
Broyden 1965
Fletcher 1970
Goldfarb 1970
Shanno 1970

63.31 ls_generalized_secant

least squares by the secant method
Barnes, 1965
Wolfe, 1959
Fletcher 1980, 6.3
seber 2003
gerber

63.32 nlcg

non-linear conjugate gradient
input:
x : nx1 start vectort

opt : struct options
fdx : gradient constraint

63.33 nlls

non-linear least squares

63.34 picard

picard iteration

63.35 poly_extrema

extrema of a polynomial

63.36 quadratic_function

evaluate quadratic function in higher dimensions

63.37 quadratic_programming

optimize by quadratic programming

63.38 quadratic_step

single step of the quadratic programming

63.39 rosenbrock

rosenbrock test function

63.40 `sqrt_heron`

Heron's method for the square root

63.41 `test_directional_derivative`

63.42 `test_dud`

63.43 `test_fzero_newton`

63.44 `test_line_search_quadratic2`

63.45 `test_ls_generalized_secant`

63.46 `test_nlcg_6_order`

63.47 `test_nlls`

```
f = w'*(p*abs(x-1).^4) + w'*(1-p)*abs(x-1).^2;
```

64 numerical-methods/pde

64.1 `laplacian2d_fundamental_solution`

65 numerical-methods/piecewise-polynomials

65.1 Hermite1

hermite polynomial interpolation in 1d

65.2 hp2_fit

fit a hermite polynomial
coefficients are derivative free
x0 : left point of first segment
x1 : right point of last segment
n : number of segments
x : sample x-value
val : sample y-value
c : coefficients (values at points, no derivatives)

65.3 hp2_predict

prediction with pw hermite polynomial
c are values at support points

65.4 hp_predict

predict with piecewise hermite polynomial

65.5 hp_regress

fit piecewise hermite polynomial
coefficients are values and derivatives

65.6 lp_count

lagrangian basis for interpolation
count number of valid samples

65.7 lp_predict

lagrangian basis piecwie interpolation, predicator

65.8 lp_regress

65.9 lp_regress_

66 numerical-methods

66.1 test_adams_bashforth

67 mathematics

mathematical functions of various kind

67.1 oversampleNZ

68 pdes

68.1 heat_equation_fundamental_solution

68.2 heat_equation_width

68.3 heat_equation_width_to_time

69 regression/@PolyOLS

69.1 PolyOLS

class for polynomial least squares

69.2 coefftest

69.3 detrend

detrending by polynomial regression

69.4 fit

fit a polynomial function
like polyfit, but returns parameter error estimates
TODO automatically activate scaleflag

69.5 fit_

fit a polynomial function

69.6 predict

predict polynomial function values

69.7 predict_

69.8 slope

slope by linear regression

70 regression/@PowerLS

70.1 PowerLS

class for power law regression

70.2 fit

fit a power law
like polyfit, but returns parameter error estimates

70.3 predict

predict with power law
S2 = diag((A*obj.C)*A');
L = Y - S;
U = Y + S;

70.4 predict_

71 regression/@Theil

71.1 Theil

Kendal-Theil-Sen robust regression

71.2 detrend

linear detrending of a set of samples by the Theil-Senn Slope

71.3 fit

fit slope and intercept to a set of sample with the Theil-Sen method

c : confidence interval $c = 2*ns*normcdf(1)$ for ns-sigma intervals
param : itercept and slope
P : confidence interval

71.4 predict

predict values and confidence intervals with the Theil-Sen method

71.5 slope

fit the slope with the Theil-Sen method

72 regression

linear and non-linear regression

72.1 Theil_Multivariate

extension of the Theil-Senn regression to higher dimensions by means of the Gauss-Seidel iteration

72.2 areg

regression using the pth-fraction of samples with smallest residual

72.3 ginireg

gini regression

72.4 hesssimplereg

hessian, gradient and objective function value of the simple
regression
 $\text{rhs} = p(1) + p(2) x + \text{eps}$

72.5 llin

solve $\|Ax - b\|_{L1}$ by means of linear programming

72.6 lsq_sparam

parameter covariance of the least squares regression

fun : model function for prediction
b : sample values
 $f(p) = b$
p : parameter at point of evaluation (preferably optimum)

72.7 polyfitd

fit a polynomial of order n to a set of sampled values and sampled
values
of the derivative

x0 must contain at least for conditioning as otherwise the
intercept
cannot be determined

72.8 regression_method_of_moments

fit linear function $\|a b x = y\|_{L2}$ by the method of moments
 $y + \text{eps} = \alpha + \beta x$

72.9 robustlinreg

fit a linear function by splitting the x-values at their median
 $(\text{med}(y_{\text{left}}) - \text{med}(y_{\text{right}})) / (\text{med}(x_{\text{left}}) - \text{med}(x_{\text{right}}))$
this approach performs poorly compared to the theil-senn operator

72.10 theil2

Theil senn-estimator for two dimensions (glm)

72.11 theil_generalised

generalization of the Theil-Senn operator to higher dimensions,
for arbitrary functions such as polynomials and multivariate
regression
either higher order polynomials or glm
c.f. "On theil's fitting method", Pegoraro, 1991

72.12 total_least_squares

total least squares

72.13 weighted_median_regression

weighted median regression
c.f. Scholz, 1978

73 set-theory

73.1 issubset

test if set B is subset of A in $O(n)$ -runtime

A : first set
B : second set
P : set of primes (auxiliary)

74 mathematics

mathematical functions of various kind

74.1 shuffle_index

75 signal-processing

75.1 asymwin

creates asymmetrical filter windows
filter will always have negative weights

76 signal-processing/autocorrelation

76.1 acf_radial

76.2 acfar1

Autocorrelation function of the finite AR1 process

$$\begin{aligned} a_k &= 1/(n-k) \sum x_{i+k} x_i + (x_i + x_{i+k})\mu + \mu^2 \\ &= r^k + 1/n \sum_{i,j} x_i x_j + 1/n \\ &\quad \text{pause} \end{aligned}$$

76.3 acfar1_2

autocorrelation of the ar1 process

76.4 acfar2

impulse response of the ar2 process

76.5 acfar2_2

autocorrelation of the ar2 process
 $X_i + a_1 X_{i-1} + a_2 X_{i-2} = 0$

76.6 ar1_cutoff_frequency

76.7 ar1_effective_sample_size

effective sample size correction for autocorrelated series

76.8 ar1_mse_mu_single_sample

standard error of a single sample of an ar1 correlated process

76.9 ar1_mse_pop

variance of the population mean of a single realisation around zero

$$E[(\mu_N - 0)^2] = E[\mu_N^2]$$

76.10 ar1_mse_range

mean standard error of the mean of a range of values taken from an ar1 process

76.11 ar1_spectrum

spectrum of the ar1 process

76.12 ar1_to_tikhonov

convert ar1 correlation to tikhonovs lambda

76.13 ar1_var_factor

variance correction factor for an autocorrelated finite process
n : [1 .. inf] population size
m : [1 .. n] samples size
rho : [-1 < rho < 1 (for convergence)] correlation of samples

76.14 ar1_var_factor_

variance of an autocorrelated finite process

76.15 ar1_var_range2

variance of sub sample starting at the end of the series
from the finite length first order autocorrelated process
$$s2 = 1/m^2 \sum_i^m \sum_j^m \rho^{-|i-j|}$$

76.16 ar1delay

approximate acf by the ar1 process
acf: autocovariance or autocorrelation function
nf : skip first samples (for mixed geometric-arithmetic series (ARMA))

76.17 ar1delay_old

autocorrelation of the residual

76.18 ar2_acf2c

determine coefficients of the ar2 process from the first two lags
of the
autocorrelation function

76.19 ar2conv

coefficients of the ar2 process determined from the two leading
correlations
of the acf [1,r1,r2,...]

76.20 ar2dof

effective samples size for the ar2 process

76.21 ar2param

ar2 parameter estimation from first two terms of acf
acf = [1 a1 a2 ...]

76.22 autocorr2

76.23 autocorr_angular

76.24 autocorr_bandpass

76.25 autocorr_decay_rate

estimate exponential decay of the autocorrelation

76.26 autocorr_effective_sample_size

effective sample size from acf

76.27 autocorr_fft

estimate sample autocorrelation function

76.28 autocorr_forest

76.29 autocorr_genton

autocorrelation function

76.30 autocorr_highpass

76.31 autocorr_lowpass

76.32 autocorr_periodic_additive_noise

76.33 autocorr_periodic_windowed

76.34 autocorr_radial

76.35 autocorr_radial_hexagonal_pattern

76.36 autocorrelation_max

77 signal-processing

77.1 average_wave_shape

extract waves with varying length from a wave train and average
their shape

77.2 bandpass

bandpass filter

77.3 bandpass_continuous_cdf

77.4 bartlett

Effective sample size factor for bartlett window
c.f. thiebaux
c.f spectral analysis-jenkins, eq. (6.3.27)
 $c = acf$
note: results seams always to be 1 tac too low
T : reduction factor for dof
for ar1 with $a = \rho^k = \exp(-k/L)$, $T = 2L$

77.5 bin1d

bin values of v sampled at x into bins bounded by "edges"
apply function v to it

77.6 bin2d

bin values of V sampled at X and Y into the grid structured grid ex
 ,ey
 apply function func to all values in the bin
 func = mean : default
 func = sum : non-normalized frequency histogram in 2D

77.7 binormrnd

generate two correlated normally distributed vectors

77.8 coherence

77.9 conv1_man

convolutions with padding

77.10 conv2_man

convolution in 2d

77.11 conv2z

77.12 conv30

convolve with rectangular window of lenght n
 circular boundaries

77.13 conv_

convolution of a with b

77.14 conv_centered

convolve x with filter window f
when length of f is even, this guarantees a symmetric result (no
off by on
displacement) by making the length of f odd at first

77.15 convz

77.16 cosexpdelay

77.17 csmooth

smooth recursively with [1,2,1]/4 kernel
function x = csmooth(x,n,p,circ)

77.18 daniell_window

Daniell window for smoothing the power spectrum
c.f. Daniell 1946
Bloomfield 2000
meko 2015

77.19 db2neper

convert decibel to neper

77.20 db2power

power ratio from db

77.21 `derive_bandpass_continuous_scale`

77.22 `derive_danielle_weight`

77.23 `derive_limit_0_acfar`

77.24 `detect_peak`

detect peaks in a vector
requires function value to fall to $p \cdot \max$ before new value is
allowed

77.25 `determine_phase_shift`

77.26 `determine_phase_shift1`

average phase and phase shift per time step of a train of waves

77.27 `doublesum_ij`

double sum of r^i

77.28 `effective_mask_size`

77.29 `effective_sample_size_to_ar1`

convert effective sample size to ar1 correlation

77.30 `fcut2Lw_gausswin`

77.31 `fcut_gausswin`

77.32 `filt_hodges_lehman`

78 `signal-processing/filters`

78.1 `circfilt2`

`smooth` (filter) the 2D image `z` with a circular disk of radius `nf`
apply periodic boundary conditions

78.2 `filter1`

`filter` along one dimension

78.3 `filter2`

`filter` columns of `x` (matlab does only support vector input)

78.4 `filter_`

invalidate values that exceed `n`-times the robust standard deviation

78.5 `filter_r_to_f0`

78.6 filter_rho_to_f0

78.7 filter_twosided

78.8 filteriir

filter adcp t-n data over time

v : nz,nt : values to be filtered

H : nt,1 : depth of ensemble

last : nt,1 : last bin above bottom that can be sampled without
side lobe interference

nf : scalar : number of reweighted iterations

when samples

- distance to bed is reference (advantageous for near-bed suspended
transport)

TODO for wash load: distance to surface is more relevant
interpolate depending on z

when depth changes, neighbouring indices do not correspond to same
relative position in the water column

relative position in the column (s-coordinate) smoothes values

near the bed: absolute distance to bed is chosen

near surface: absolute distance to surface is chosen

-> cubic transformation of index

faster and avoid aliasing (smoothing along z)

resample ensemble to same number of bins in S -> filter ->

resample back

use nonlinear transform z-s coordinates

-> resampling has to be local (Hi -> H-filtered)

filtered profile coordinates to sample coordinates

zf -> zi (special transform)

corresponding indices and fractions

filtration step (update of hf and vf)

sample coordinates to updated profile coordinates

(the inverse step is actually not necessary)

write filtered value

78.9 filterp

78.10 filterp1

fir filter with some fancy extras

78.11 filterstd

78.12 gaussfilt2

smooth (filter) the 2D image z with a gaussian window
apply periodic boundary conditions

78.13 lowpass_discrete

design coefficients of a low pass filter with specified cut of
frequency
and sampling period
analogue low pass with pole at $s = -\omega_c = 1/\tau = 1/RC$
 $H_a = \tau / (\tau + s) = 1 / (1 + \omega_c s)$

78.14 meanfilt2

filter with a rectangular window along both dimensions

78.15 medfilt1_man

moving median filter, supports columnwise operation

78.16 medfilt1_man2

moving median filter with special treatment of boundaries

78.17 `medfilt1_padded`

median filter with padding

78.18 `medfilt1_reduced`

median filter with padding

78.19 `trifilt1`

filter with triangular window
trifilt1 is ident to twice applying rectfilt1 (meanfilt1) with half
the domain size
note : infinitely many convolution yield a gaussian

78.20 `trifilt2`

filter with a triangular window along both dimensions

79 signal-processing

79.1 `firls_man`

design finite impulse response filter by the least squares method

79.2 `fit_spectral_density`

fit spectral densities (probability distributions)

79.3 `fit_spectral_density_2d`

fit spectral densities

79.4 `fit_spectral_density_radial`

fit spectral densities

79.5 `flattopwin`

the flat top window

79.6 `frequency_response_boxcar`

frequency response of a boxcar filter

79.7 `freqz_boxcar`

frequency response of a boxcar filter

79.8 `gaussfilt1`

filter data series with a gaussian window, assumes periodic bc

79.9 `hanchangewin`

hanning window for change point detection

79.10 `hanchangewin2`

nanning window for chage point detection

79.11 `hanwin`

hanning filter window

79.12 hanwin_

hanning filter window

79.13 high_pass_1d_simple

79.14 kaiserwin

kaiser filter window

79.15 kalman

Kalman filter

79.16 lanczoswin

Lanczos window

79.17 last

lake tail, but for matrices

79.18 maxfilt1

79.19 meanfilt1

moving average filter with special treatment of the boundaries

79.20 mid_term_single_sample

variance of single sample, mid term

79.21 minfilt1

79.22 minmax

79.23 mu2ar1

error variance of the mean of the finite length ar1 process

$(\mu)^2 = (\sum \text{epsi})^2 = \sum_i \sum_j \text{epsi}_i \text{epsi}_j = \text{sum_ii}(\text{rho}, n)/n^2$
this has the limit s^2 for $\text{rho} \rightarrow 1$

79.24 mysmooth

79.25 nanautocorr

autocorrelation with nan-values

79.26 nanmedfilt1

medfilt1, skipping nans

79.27 neper2db

convert neper to db

79.28 oscillator_noisy

80 signal-processing/passes

80.1 bandpass1d

80.2 bandpass1d_fft

filter input vector with a spatial (two-sided) bandpass in fourier
space

80.3 bandpass1d_implicit

80.4 bandpass2

bandpass filter

80.5 bandpass2d

80.6 bandpass2d_convolution

80.7 bandpass2d_fft

80.8 bandpass2d_ideal

80.9 bandpass2d_implicit

bandpass filter the surface x by solving the implicit relation:

80.10 bandpass2d_iso

80.11 bandpass_arg

determine correlation coefficient from frequency of mode for the
symmetric

80.12 bandpass_f0_to_rho

correlation coefficient for the p th-order symmetric bandpass filter
with
maximum at f_0 (when $\rho_{lp} = \rho_{hp}$)

80.13 bandpass_max

80.14 bandpass_max2

80.15 highpass

high pass filter

80.16 highpass1d_fft_cos

filter the input vector with a cosine-shaped highpass in frequency
space

80.17 `highpass1d_implicit`

80.18 `highpass2d_fft`

80.19 `highpass2d_ideal`

80.20 `highpass2d_implicit`

80.21 `highpass_arg`

80.22 `highpass_fc_to_rho`

80.23 `lowpass`

`low pass filter`

80.24 `lowpass1d_fft`

80.25 `lowpass1d_implicit`

80.26 lowpass2

design low pass filter with cutoff-frequency f1

80.27 lowpass2d_anisotropic

80.28 lowpass2d_convolution

this function is computationally inefficient and serves merely for
illustration
and tests

80.29 lowpass2d_fft

note : this function is for testing purposes only,
directly multiply the ft of the signal with the ft of the
filter
to obtain the filtered signal in a single step
function y = lowpass2d_fft(x,rho,a,order)

80.30 lowpass2d_ideal

lowpass filter the input x in the Frequency Domain

TODD no need to provide dx, follows from size of x
function [y,S,R,r]=lowpass2d_ideal(x,L,dx,varargin)

80.31 lowpass2d_implicit

function [y] = lowpass2d_implicit(x,rho,a,order,direct)

80.32 lowpass_arg

80.33 lowpass_fc_to_rho

80.34 lowpass_iir

iir-low pass

80.35 lowpass_iir_symmetric

two-sided iir low pass filter (for symmetry)

80.36 lowpassfilter2

low-pass filter of data

81 signal-processing

81.1 peaks_man

peaks of a periodogram

82 signal-processing/periodogram

82.1 periodogram

compute the normalized periodogram

82.2 periodogram_2d

compute the normalized periodogram in two dimensions

82.3 periodogram_align

82.4 periodogram_angular

```
input:
    Sxy : nxn
output:
    Sra : n/2*(pi*n/2)
    angle
function [Sa,angle,A] = periodogram_angular(Sxy,L,nf)
```

82.5 periodogram_bartlett

estimate the spectral density nonparametrically with Bartlett's method

82.6 periodogram_bootstrap

82.7 periodogram_confidence_interval

confidence interval for periodogram values

82.8 periodogram_filter

82.9 periodogram_median

82.10 periodogram_normalize

82.11 periodogram_normalize_2d

82.12 periodogram_p_value

82.13 periodogram_qq

qq-plot of a spectral density estimate by smoothing against the
expected
beta-density

82.14 periodogram_quantiles

quantiles of a periodogram

82.15 periodogram_radial

function [Sr,fri,se,count] = periodogram_radial(S2d,L)

compute the radially averaged density

input:

S2d : 2-dimensional density or periodogram

L =[Lx,Ly] : domain length

output:

S_r.mu : radially averaged periodogram

S_r.normalized : normalized radially averaged periodogram

A : matrix operator s that $S_r = (A \cdot A')^{-1} A' \cdot S2d$

f_r : radial frequencies, at which radial periodogram is determined
discretized in same interval as the 2d-density : $f = 1/L$

Definitions:

radial wavenumber, identical to circumferences of circles
centred at origin with radial frequency fr
 $k_r = 2\pi \cdot f_r$

radially averaged periodogram:
$$S_r(k_r) = \frac{1}{k_r} \int_0^{k_r} S2d(k_r,s) ds$$
$$= \frac{1}{(2\pi)} \int_0^{2\pi} S2d(k_r,\theta) d\theta$$
$$\sim \frac{1}{(2\pi)} \sum_{nt} S2d(k_r,\theta) * (2\pi/nt)$$
$$\sim \frac{1}{nt} \sum_{nt} S2d(k_r,\theta)$$

```

nt ~ k_r/df = k_r*L
normalization:
    S_r.normalize = S_r/int_0^inf S_r dfr
                  ~ S_r/(sum_0^nr S_r Delta fr)

note : the radially averaged "periodogram", is actually a density
estimate,
      for radial frequencies fr hat are not small

when S is flattened into a vector, the isotropic part of the 2D
density can be recovered with:
S_iso    = (A*S_radial)
S_radial = A^-1 S_hat

```

82.16 periodogram_std

standard deviation of a periodogram

82.17 periodogram_test_periodicity

test a periodogram for hidden periodic frequency components

```

function [p,ratio,maxShat,mdx,fdx,S] = periodogram_test_periodicity
(fx,Shat,nf,fmin,fmax,S,mode)

```

```

input:
    fx : frequengcies
    Shat : corresponding periodogram values
    nf  : number of bins to test for periodicity, ignored when S
is given
    fmin, fmax : frequency range limits to test
    S      : exact (a priori known theoretical spectral density,
must not be estimated from the periodogram)
    mode : automatically set to "exact", when S given
           inclusive : estimate density by smoothing including the
central bin
           exclusive : estimate density by smoothing excluding the
central bin
    note: inclusive and exclusive lead to different distribution
but identical p-values

```

TODO pass L and not fx

82.18 periodogram_test_periodicity_2d

test a periodogram for hidden periodic frequency components

```
[p,stat,ratio] = periodogram_test_periodicity_2d(b, nf, bmsk, fmsk,
ns)
```

input:

```
  b  (nx * ny): image to test for presence of hidden
periodicities,
      i.e. periodicities where the frequency is not known a
      priori
  nf  = nfr or [nfx, nfy]
      radius of circular disk (in number of bins) used for
      smoothing
      the periodogram to estimate the spectral density,
      or axes of ellipses for smoothing
      when b is not square a good choice is nfx/nfy ~ Lx/Ly
  bmsk : mask in real space selecting parts of the image to
include in
      the analysis default is entire image
      the mask can have non-integer values to feather the
      borders of the mask
  fmsk : mask in frequency selecting frequencies to test for
periodicity
      default is all frequencies
      note: when b is real, one half plane can always be
      excluded
      because of symmetry. This slightly increases the
      significance
  ns  : number of samples for the monte-carlo determination of
the test statistics, mc is only used when parts of the
image are masked
      otherwise the analytic test statistic is used
```

influence of masking the input file:

- the root-mean-square energy of the ordinates is proportional to the number of unmasked points
- values in the periodogram are not any more linearly independent so that the dof of the filter window is not nf^2

82.19 periodogram_test_stationarity

test a periodogram for stationarity

note : the method works, but is of little practical use,
as it requires about 50 periods and a small dx to detect a
frequency change by a factor of 2

82.20 periodogram_welsh

83 signal-processing

83.1 polyfilt1

polynomial filter,
can be achieved by iteratively processing the data with
a mean (zero-order) filter

83.2 qmedfilt1

medfilt1, after fitting a quadratic polynomial

83.3 quadratfilt1

83.4 quadratwin

83.5 randar1

generate random ar1 process
e1 = randar1(sigma,p,n,m)

83.6 randar1_dual

draw random variables of two correlated ar1 processes

83.7 randar2

generate ar2 process

83.8 randarp

randomly generate the instance of an ar-p process

83.9 rectwin

rectangular window

83.10 recursive_sum

83.11 select_range

83.12 smooth1d_parametric

smooth position of $p_0=x_0, y_0$ between $p_1=x_1, y_1$ and $p_2=x_2, y_2$,
so that distance to p_1 and p_2 becomes equal
and the chord length remains the same

83.13 smooth2

smooth vectos of X

83.14 smooth_man

83.15 smooth_parametric

smooth a parametric function given in x-y coordinates
matvec2x2(R,[dxc;dyc])

83.16 smooth_parametric2

parametrically smooth the curve

83.17 smooth_with_splines

83.18 smoothfft

filter with fast fourier transform

84 signal-processing/spectral-density

84.1 hex_angular_pdf

84.2 hex_angular_pdf_max

84.3 hex_angular_pdf_max2par

84.4 spectral_density_ar2

84.5 spectral_density_area

integrate the spectral density over the positive half axis

84.6 spectral_density_estimate_2d

84.7 spectral_density_flat

flat spectral density of a random vector with iid elements

84.8 spectral_density_forest

84.9 spectral_density_gausswin

84.10 spectral_density_lorentzian

lorentzian spectral density

84.11 spectral_density_lorentzian_max

mode (maximum) of the lorentzian spectral density

84.12 spectral_density_lorentzian_max2par

transform maximum of the lorentzian spectral density to its
distribution parameters

84.13 spectral_density_lorentzian_scale

normalization scale of the lorentzian spectral density

84.14 spectral_density_maximum_bias_corrected

84.15 spectral_density_periodic_additive_noise

84.16 spectral_density_rectwin

84.17 spectral_density_wperiodic

85 signal-processing

85.1 spectrogram

spectrogram

85.2 sum_i_lag

sum of ar1 matrix with lag
 $\sum_{i=1}^n \rho^{|i-k|}$

85.3 sum_ii

sum of ar1 matrix
 $\sum_{i=1}^n \sum_{j=1}^n \rho^{|i-j|}$
this is for the variance, take square root for the standard
deviation factor

85.4 `sum_ii_`

85.5 `sum_ij`

sum of ar1 matrix
 $\sum_{i=1}^n \sum_{j=1}^m r^{|i-j|}$

85.6 `sum_ij_`

85.7 `sum_ij_partial_`

85.8 `sum_multivar`

sum of matrix entries of bivariate ar1 process

85.9 `test_acfar1`

85.10 `tikhonov_to_ar1`

convert coefficient of the tikhonov regularization to correlatioon
of the ar1 process

85.11 `trapwin`

trapezoidal filter window

85.12 triwin

triangular filter window

85.13 triwin2

triangular filter window

85.14 tukeywin_man

85.15 varar1

error variance of a single sample of a finite length ar1 process
with respect to the mean, averaged over the population

85.16 welch_spectrogram

welch spectrogram

85.17 wfilt

filter with window

85.18 winbandpass

filter with bandpass

86 signal-processing/windows

86.1 circwin

86.2 danielle_window

danielle fourier window

86.3 gausswin

86.4 gausswin1

86.5 gausswin2

86.6 radial_window

radial filter window in the 2d-frequency domain

86.7 range_window

range of values within a certain range of indices (window)

86.8 rectwin_cutoff_frequency

86.9 std_window

moving block standard deviation

86.10 window2d

86.11 window_make_odd

87 signal-processing

87.1 winfilt0

filter with window

87.2 winlength

window length for desired cutoff frequency
power at f_c is halved
 $H(wf) = 1/\sqrt{2} H(f)$
if the filter window were used as a low pass filter
note: the user should prefer a windowed ideal low pass filter
TODO, relate this to DOF

87.3 wmeanfilt

mean filter with window

87.4 wmedfilt

median filter with window

87.5 wordfilt

weighted order filter

87.6 wordfilt_edgeworth

weighed order filter

87.7 wrapphase

87.8 xar1

87.9 xcorr_man

cross correlation of two sampled ar1 processes

88 sorting

88.1 sort2

sort two numbers

88.2 sort2d

sort elements of matrix in X
returns row and column index of sorted values

89 spatial-pattern-analysis/@Spatial_Pattern

89.1 Spatial_Pattern

class for analysis of remotely sensed and model generated
vegetation patterns

89.2 analyze_grid

analyze a 2D spatial pattern, estimate regularity and test for
periodicity

89.3 analyze_transect

analyze 1D transect through a spatial pattern,
either remotely sensed or model generated

89.4 clear_1d_properties

89.5 clear_2d_properties

89.6 fit_parametric_densities

fit parametric spectral densities to the empirical density

89.7 imread

read an image file containing a pattern, mask and geospatial data

89.8 plot

plot the pattern or densities

89.9 plot_transect

plot 1D pattern

89.10 prepare_analysis

89.11 report

report statistics of analysis

89.12 resample_functions

resample empirical densities to a common grid

89.13 tabulate

summarize properties of multiple patterns in a single struct

90 spatial-pattern-analysis/@Spatial_Pattern_Array

90.1 Spatial_Pattern_Array

container class for Spatial_Pattern objects

90.2 analyze

analyze spatial patterns

90.3 assign_regions

90.4 export_shp

90.5 fetch

determine the sampling interval for fetching images from the Google
satellite
server and later processing

90.6 generate_filename

90.7 quality_check

91 spatial-pattern-analysis

91.1 approximate_ratio_distribution

```
input :
bmsk : region selected for periodicity test (smoothes the
      periodogram)
nf    : radius of smoothing window (in bins) for estimating the
      spectral density
nsample : number of repetitions to estimate the ratio distribution
        recommended at

output:
  pr    : probabilities for quantiles
  qr1   : quantiles of the distribution for bin m
  qrn   : quantiles of the distribution for the maximum of bins
        selected by fmsk
  ratio : ratios for each frequency bin and iteration (only for
        last block, for testing)

input:
  bmsk : mask region pattern/interest in the real domain
  nf    : smoothing window radius in the frequency domain for
        density estimation
  ns    : number of samples for the monte-carlo simulation
  fmsk  : mask frequencies of interest
  mdx   : selection of an a-priori known frequency bin

note the following complications:
- problem 1 : ratio locally differs near fr=0, fx,fy=fmax and
  fx,fy=fmax/2
- fits of the fisher or beta distribution are highly unstable
```

91.2 banded_pattern

91.3 hexagonal_pattern

```
function [z, x, y, xx, yy, xe, ye] = hexagonal_pattern(fc,n,L,  
    angle0_rad,scale,sbm,p,q)
```

spot pattern of unit amplitude

```
output : z : pattern  
        x : x-coordinate  
        y : y-coordinate
```

Note : $z_{\text{gap}} = 1 - z_{\text{spot}}$

91.4 patch_size_1d

91.5 patch_size_2d

91.6 pattern_isotropic_rotated

91.7 reconstruct_isotropic_density

91.8 separate_isotropic_from_anisotropic_density

91.9 suppress_low_frequency_lobe

92 spatial-statistics

92.1 cov_cell_averages_1d

determine covariance between grid cell averaged values of a
stationary
stochastic process on an equispaced grid

$$\begin{aligned}\text{cov}(e_{ij}, e_{kl}) &= E[(e_{ij} - \mu)(e_{kl} - \mu)] \\ &= 1/dx^2 E[\int (e(x_1) - \mu) dx_1 \int (e(x_2) - \mu) dx_2] \\ &= 1/dx^2 E[\int \int (e(x_1) - \mu)(e(x_2) - \mu) dx_1 dx_2] \\ &= 1/dx^2 \int \int \text{cov}(x_2 - x_1) dx_1 dx_2\end{aligned}$$

$$f_{ij} = \int_{x_i - dx/2}^{x_i + dx/2} f(x) dx$$

integrals approximated by Gauss' method

92.2 cov_cell_averages_2d

determine covariance between grid cell averaged values of a
stationary
stochastic process on an equispaced grid

$$\begin{aligned}\text{cov}(e_{ij}, e_{kl}) &= E[(e_{ij} - \mu)(e_{kl} - \mu)] \\ &= 1/dx^2 1/dy^2 E[\int \int (e(x_1, y_1) - \mu) dx_1 dy_1 \int \int (e(x_2, y_2) - \mu) dx_2 dy_2] \\ &= 1/dx^2 1/dy^2 E[\int \int \int \int (e(x_1, y_1) - \mu)(e(x_2, y_2) - \mu) dx_1 dy_1 dx_2 dy_2] \\ &= 1/dx^2 1/dy^2 \int \int \int \int \text{cov}(x_2 - x_1, y_2 - y_1) dx_1 dy_1 dx_2 dy_2\end{aligned}$$

$$f_{ij} = \int_{x_i - dx/2}^{x_i + dx/2} \int_{y_i - dy/2}^{y_i + dy/2} f(x, y) dx dy$$

integrals approximated by equal spaced mid-point intervalles,
this allows to reduce the double-integral along each dimension into
a
single integral and hence to reduce the computational effort from m^4
to m^2

93 special-functions

93.1 `bessel_sphere`

spherical Bessel function of the first kind

93.2 `besseliln_large_x`

93.3 `beta_man`

93.4 `betainc_man`

93.5 `digamma_man`

93.6 `exp10`

93.7 `hankel_sphere`

spherical Hankel function for the far field (incident plane wave)
first kind

93.8 `hermite`

probabilistic's hermite polynomial by recurrence relation

input :
n : order
x : value

```
output:
f : H_n(x)
df : d/dx H_n(x)
```

93.9 laguerre_roots

93.10 lambertw_numeric

lambert-w function

93.11 legendre_man

legendre polynomials

93.12 neumann_sphere

spherical Neumann function
Bessel function of the second kind

94 statistics

94.1 atan_s2

stadard deviation of the arcus tangens by means of taylor expansion

94.2 binomial

generalized binomial coefficient, working for non-integer arguments
,
in contrast to the matlab buildin function nchoosek

95 statistics/circular

95.1 circular_fmoment

95.2 circular_fquantile

95.3 circular_fstd

95.4 circular_fvar

96 statistics

96.1 coefficient_of_determination

96.2 conditional_expectation_normal

96.3 correlation_confidence_pearson

confience intervals of the correlation coefficient
c.f. Fischer 1921

97 statistics/distributions

97.1 PDF

class for quasi-distributions from a set of sampling points

98 statistics/distributions/anisotropic

98.1 anisotropic_pattern

98.2 anisotropic_pattern_acf

98.3 anisotropic_pattern_pdf

99 statistics/distributions/beta

99.1 beta_kurt

99.2 beta_mean

99.3 beta_moment2par

transform central moments (mean and sd) to parameters of the beta
function

99.4 beta_skew

99.5 beta_std

100 statistics/distributions/bivariate-normal

100.1 binorm_separation_coefficient

separation coefficient of a bimodal normal distribution

100.2 binormcdf

bio-modal gaussian distribution

100.3 binormfit

fit sum of to normal distribution to a histogram

100.4 binormpdf

101 statistics/distributions/chi2

101.1 chi2_kurt

101.2 chi2_mean

101.3 chi2_skew

101.4 chi2_std

102 statistics/distributions/circular-normal

102.1 wnormpdf

wrapped normal distribution to the unit circle
c.f. stephens

103 statistics/distributions/edgeworth

103.1 edgeworth_cdf

edgeworth expansion of an unknown cumulative distribution
with mean mu, standard deviation sigma, and third and fourth
cumulants
c.f. Rao 2010

103.2 edgeworth_pdf

probability density of and unknown distribution
with mean mu, standard deviation sigma, and third and fourth
cumulants
c.f. Rao 2010

104 statistics/distributions/exp

104.1 exppdf_max2par

105 statistics/distributions/fisher

105.1 fisher_mean

105.2 fisher_moment2par

105.3 `fisher_std`

106 `statistics/distributions/gamma`

106.1 `gamma_mean`

106.2 `gamma_mode`

106.3 `gamma_mode2par`

106.4 `gamma_moment2par`

`transform modes (mu,sd) to parameters of the gamma distribution`

106.5 `gamma_std`

106.6 `gamma_stirling`

106.7 `gampdf_man`

106.8 `generalized_gamma_mean`

107 statistics/distributions/hotelling-t2

107.1 t2cdf

Hotelling's T-squared cumulative distribution

107.2 t2inv

inverse of Hotelling's T-squared cumulative distribution

108 statistics/distributions/kurt-normal

108.1 kurtncdf

108.2 kurtnpdf

109 statistics/distributions/log-triangular

109.1 logtrialtcdf

pdf of a logarithmic triangular distribution

109.2 logtrialtinv

inverse of the logarithmic triangular distribution
= (d F log(a) log(b) + a log(b) - b log(a) - d F log(a) log(c) - a
log(c) + d F log(b) log(c) + b log(c) - d F log²(b))/((log(a)
- log(b)) W((a^{-1/(log(a) - log(b))}) (b<sup>-log(c)/log(a) - 1/
log(a)</sup>) c^{-log(a)/(log(a) - log(b))}) (-d F log²(b) + a log(b)
) + d F log(a) log(b) + d F log(c) log(b) - b log(a) - a log(c)
+ b log(c) - d F log(a) log(c)))/(log(a) - log(b)))

$$x = \frac{(d F \log(a) \log(b) + a \log(b) - b \log(a) - d F \log(a) \log(c) - a \log(c) + d F \log(b) \log(c) + b \log(c) - d F \log^2(b)) / ((\log(a) - \log(b)) W((a^{-1/(\log(a) - \log(b))}) (b^{-\log(c)/\log(a) - 1/\log(a)}) c^{-\log(a)/(\log(a) - \log(b))}) (-d F \log^2(b) + a \log(b) + d F \log(a) \log(b) + d F \log(c) \log(b) - b \log(a) - a \log(c) + b \log(c) - d F \log(a) \log(c))) / (\log(a) - \log(b)))$$

109.3 logtrialtmean

mean of the logarithmic triangular distribution

109.4 logtrialtpdf

density of the logarithmic triangular distribution

109.5 logtrialtrnd

109.6 logtricdf

cumulative distribution of the logarithmic triangular distribution

109.7 logtriinv

inverse of the logarithmic triangular distribution

109.8 logtrimean

mean of the logarithmic triangular distribution

109.9 logtripdf

probability density of the logarithmic triangular distribution

109.10 logtirnd

110 statistics/distributions/log-uniform

110.1 logu_median

median of the log-uniform distribution

110.2 logucdf

probability density of the logarithmic uniform distribution

110.3 logucm

central moments of the log-uniform distribution

110.4 loguinv

inverse of the log-uniform distribution

110.5 logumean

mean of the log-uniform distribution

110.6 logupdf

pdf of the log uniform distribution

110.7 logurnd

random numbers following a log-uniform distribution

110.8 loguvar

variance of the log-uniform distribution

111 statistics/distributions/loglog

111.1 loglogpdf

112 statistics/distributions/lognormal

112.1 logn_corr

correlation of two log-normal random variables, where the log of
the variables
is correlated with r

112.2 logn_cov

covariance of two log-normally distributed random variables,
 $\text{cov}(ea, eb) = \text{cov}(\exp(\mu_a + s_a z_a), \exp(\mu_b + s_b z_b))$
where z_a, z_b are standard normal distributed and correlated

112.3 logn_mean

112.4 logn_mode

mode (maximum) of the log-normal density

112.5 logn_mode2par

112.6 logn_moment2par

transform the mode (mu,sd) to parameters of the log normal distribution

112.7 logn_moment2par_correlated

112.8 logn_param2moment

transform parameters to mode (mu, sd) for the log normal distribution

112.9 logn_skewness

112.10 logn_std

112.11 lognpdf_

log normal distribution called by modes rather than parameters

112.12 lognpdf_entropy

113 statistics/distributions/logskew

113.1 logskewcdf

113.2 logskewpdf

114 statistics/distributions/mises

114.1 mises_max2par

114.2 mises_std

114.3 mises_var

114.4 misesn_max2par

114.5 misesnpdf

114.6 misespdf

115 statistics/distributions

115.1 ncx2_moment2par

116 statistics/distributions/normal

116.1 normpdf_entropy

116.2 normpdf_mode

116.3 normpdf_mode2par

117 statistics/distributions/passes

117.1 bandpass1d_continuous_pdf

```
function [S_bp,Sc] = spectral_density_bandpass_continuous(fx,fc,  
    order,normalize,pp)
```

output :

S_bp : spectral density of the bandpass filter in continuous space
limit case of the discrete bandpass for $dx \rightarrow 0$

Sc : scale factor to normalize area to 1, if normalize = true

input :

f : frequency (abszissa)

fc : central frequency, location of maximum on abszissa

order : number of times filter is applied iteratively, not
necessarily integer

normalize : normalize area under curve $\int_0^\infty S(f) df = 1$, if
not maximum $S(fc) = 1$

pp : powers for recombination of the lowpass filter

117.2 bandpass1d_continuous_pdf_max

maximum of the bandpass spectral density

117.3 bandpass1d_continuous_pdf_max2par

transform mode (maxima) of the bandpass spectral density into the
paramter
of the underlying distribution

117.4 bandpass1d_continuous_pdf_scale

normaliztation scale of the spatial bandpass density

117.5 bandpass1d_discrete_pdf

spectral density of the discrete spatial (two-sided) bandpass
filter

117.6 bandpass2d_discrete_pdf

117.7 bandpass2d_pdf_exact

function Sb = bandpass2d_pdf(fr,a,order)
not normalized, max (S) = 1;

117.8 bandpass2d_pdf_hankel

117.9 bandpass2d_pdf_mode

117.10 bandpass2d_pdf_mode2par

transform mode (maxima) of the bandpass spectral density into the
paramter
of the underlying distribution

117.11 bandpass2d_pdf_scale

117.12 highpass1d_continuous_pdf

```
function [S_bp,Sc] = spectral_density_highpass_continuous(fx,fc,
    order,normalize,pp)

output :
S_bp : spectral density of the highpass filter in continuous space
    limit case of the discrete highpass for dx -> 0
Sc   : scale factor to normalize area to 1, if normalize = true

input :
f     : frequency (abszissa)
fc    : central frequency, location of maximum on abszissa
order : number of times filter is applied iteratively, not
    necessarily integer
normalize : normalize area under curve  $\int_0^\infty S(f) df = 1$ , if
    not maximum  $S(fc) = 1$ 
pp    : powers for recombination of the lowpass filter
```

117.13 highpass1d_discrete_cos_pdf

cosine shaped spectral density of a highpass filter

117.14 highpass1d_discrete_pdf

spectral density of the pth-order high-pass

Note that there are two alternative definitions

$S_{hp} = S_{h1}^p = (1 - S_{l1})^p$ (recursive highpass-filtering)

or $S_{hp} = (1 - S_{lp}^p)$ (1 - recursive lowpass-filtering)

here, recursive highpass filtering is represented

$$S_h = |F \cdot A_h|^2$$

$$S_h^{(1/2p)} = F \cdot A_h = F(I - A_l)$$

$$= F(I - A_l)$$

$$= F(I - F^{-1} S_l^{1/2} F)$$

$$= (F F^{-1} - S_l^{1/2}) F$$

$$= (I - S_l^{(1/2)}) F$$

```
function [S_h,S_h1] = spectral_density_hp(f,r0,fmax,order,varargin)
```

117.15 `highpass2d_discrete_pdf`

117.16 `highpass2d_pdf`

117.17 `highpass2d_pdf_hankel`

117.18 `lowpass1d_continuous_pdf`

117.19 `lowpass1d_continuous_pdf_scale`

117.20 `lowpass1d_discrete_pdf`

117.21 `lowpass1d_one_sided_pdf`

117.22 `lowpass2d_discrete_acf`

truncated, not wrapped at the end

117.23 `lowpass2d_discrete_pdf`

117.24 lowpass2d_pdf

117.25 lowpass2d_pdf_hankel

spectral density of the two-dimensional lowpass filter with autocorrelation

$$r = \exp(-a\sqrt{x^2 + y^2})$$

efficiently estimated with gauss-laguerre integration and 1D-FFT:

for a radially symmetric function, the radial density is
 $S_r(r) = S_{2d}(r,0) = S_{2d}(0,r)$
with density S_{2d} and autocorrelation R_{2d}
 $S_{2d} = F_{2d}^{-1}(R_{2d})$
by the slicing theorem:
 $S_{2d}(x,0) = F_{1d}^{-1}(\int R_{2d}(x,y) dy)$

117.26 lowpass2d_pdf_series

118 statistics/distributions

118.1 pdfsample

pdf from sample distribution
Note: better use kernel density estimates

119 statistics/distributions/phase-drift

119.1 phase_drift_acf

119.2 phase_drift_acf_2d

119.3 `phase_drift_cdf`

119.4 `phase_drift_inv`

119.5 `phase_drift_parallel_acf`

119.6 `phase_drift_parallel_pdf`

119.7 `phase_drift_parallel_pdf_max`

119.8 `phase_drift_parallel_pdf_max2par`

119.9 `phase_drift_parallel_pdf_mode2par`

119.10 `phase_drift_patch_size_distribution`

119.11 `phase_drift_pdf`

spectral density of a fourier series where the phase undergoes
brownian motion
with standard deviation s per unit distance

119.12 `phase_drift_pdf_2d`

119.13 `phase_drift_pdf_mode`

mode (maximum) of the spectral density of the fourier series with brownian phase

119.14 `phase_drift_pdf_mode2par`

transform mode to parameters of the brownian phase spectral density

119.15 `phase_drift_pdf_reg2par`

119.16 `phase_drift_pdf_scale`

normalization scale of the brownian phase spectral density

120 `statistics/distributions/skew-normal`

120.1 `skew_generalized_normal_fit`

120.2 `skew_generalized_normpdf`

120.3 `skewcdf`

120.4 skewparam_to_central_moments

120.5 skewpdf

skew-normal distribution
c.f. Azzalini 1985

120.6 skewpdf_entropy

121 statistics/distributions/triangular

121.1 tricdf

cumulative distribution of the log-triangular distribution

121.2 triinv

inverse of the triangular distribution

121.3 trimedian

median of the triangular distribution

121.4 tripdf

probability density of the triangular distribution

121.5 trirnd

random numbers of the triangular distribution

122 statistics/distributions/weibull

122.1 wbl_std

123 statistics/distributions/wrapped-normal

123.1 normpdf_wrapped

123.2 normpdf_wrapped_mode

123.3 normpdf_wrapped_mode2par

124 statistics

124.1 error_propagation_fraction

124.2 error_propagation_product

124.3 example_standard_error_of_sample_quantiles

124.4 f_var_finite

reduction of variance when sampling from a finite population
without replacement

124.5 gaussfit3

124.6 gaussfit_quantile

124.7 geoserr

124.8 geostd

124.9 hodges_lehmann_correlation

hodges_lehmann correlatoon coefficient
c.f. Shamos 1976
c.f. Bickel and Lehmann 1976
c.f. rousseeuw 1993
c.f. Shevlyakov 2011

124.10 hodges_lehmann_dispersion

dispersion determined by the hodges lehman method
asymptotic efficiency of dispersion estimates:
standard deviation: $E(s - \hat{s})/s = 2/\sqrt{2n} \sim 0.707/\sqrt{n}$
(100%)
hodges lehmann dispersion $E(s - \hat{s})/s = (\pi/3)^2 / (\sqrt{2n}) \sim$
 $0.775/\sqrt{n}$ (91%)
mad $E(s - \hat{s})/s \sim 1.17 s/\sqrt{n}$
(60%)
c.f. Shamos 1976
c.f. Bickel and Lehmann 1976
c.f. rousseeuw 1993
nb: rousseeuw uses the 25th percentile, which is more efficient for
small sample sizes

125 statistics/information-theory

125.1 akaike_information_criterion

akaike information criterion

serr : rmse of model prediction
n : effective sample size
k : number of parameters

c.f. akaike (1974)
c.f. sugiura 1978

125.2 bayesian_information_criterion

bayesian information criterion

126 statistics

126.1 jackknife_block

126.2 kurtosis_bias_corrected

bias corrected kurtosis

126.3 limit

limit a by lower and upper bound

126.4 logfactorial

approximate log of the factorial

126.5 lognfit_quantile

126.6 max_exprnd

126.7 maxnnormals

expected maximum of n normal variables
c.f. Wolperts
this is the median, not the mean of the maximum!
see median of gumbel

126.8 mean_angle

126.9 mean_max_n

126.10 mean_min_n

126.11 midrange

mid range of columns of X

126.12 minavg

solution of the minimum variance problem
minimise the variance of the weighted sum of n-independent
random variables with equal mean and individual variance

126.13 mode_man

127 statistics/moment-statistics

127.1 autocorr_man3

autocorrelation of the columns of X

127.2 autocorr_man4

autocorrelation for x if x is a vector, or individually for the columns of x if x is a matrix

c.f. box jenkins 2008 eq. 2.1.12

Note that it is faster to compute the acf in frequency space as done in the matlab internal function

127.3 autocorr_man5

autocorrelation of the columns of X

127.4 blockserr

estimate the standard error of potentially sequentially correlated data

by blocking

block length should be sufficiently larger than correlation length and sufficiently smaller than data length

this uses a sliding block approach, which reduces the variation of the error estimate

127.5 comoment

non-central higher order moments of the multivariate normal distribution

c.f. Moments and cumulants of the multivariate real and complex Gaussian distributions

note : there seem to be some typos in the original paper, for x^4 c_{ii}^2 , the square seems to be missing

mu : nx1 mean vector
C : nxn covariance matrix
k : nx1 powers of variables in moments

127.6 corr_man

correlation of two vectors

127.7 cov_man

covariance matrix of two vectors

127.8 dof

mininum number of support points
for a polynomial of degree order in dim dimensions

127.9 edgeworth_quantile

inverse edgeworth expansion
c.f. cornis fisher 1937
c.f. Rao 2010
c.f. 2.50 in hall
CHERNOZHUKOV 3.3

127.10 effective_sample_size

effective sample size of the weighted mean of uncorrelated data
c.f. Kish

127.11 f_correlation

correction factor for standard error of the mean of n ar1-
correlated iid samples

127.12 `f_finite`

reduction factor of standard error for sampling from a finite
distribution
without replacement

127.13 `lmean`

mean of $x.^l$, not of `abs`

127.14 `lmoment`

l -moment of vector `x`

127.15 `maskmean`

mean of the masked values of `X`

127.16 `masknanmean`

127.17 `mean1`

mean of `x`

127.18 `mean_man`

mean and standard error of `X`

127.19 `mse`

mean squared error of residual vector `res`
this is de-facto the `std` for an unbiased residual

127.20 nanautocorr_man1

autocorrelation of a vector with nan-values

127.21 nanautocorr_man2

autocorrelation of a vector with nan-values

127.22 nanautocorr_man4

compute autocorrelation for x if x is a vector, or individually
for the
columns of x if x is a matrix
box jenkins 2008 eq. 2.1.12
TODO nan is problematic!
Note that it is faster to compute the acf in frequency space
as done in the matlab internal function

127.23 nancorr

(co)-correlation matrix when samples a NaN

127.24 nancumsum

cumulative sum, setting nan values to zero

127.25 nanlmean

mean of the l-th power of the absolute value of x

127.26 nanr2

coefficient of determination when samples are invalid

127.27 nanrms

root mean square value when sample contains nan-values

127.28 nanrmse

root mean square error from vector of residuals
this is de-facto the std for an unbiased residual

127.29 nanserr

standard error of x with respect to mean when x contains nan values

127.30 nanwmean

weighted mean
 $\min_x \sum w (x - \mu)^2 \Rightarrow \mu = \frac{\sum wx}{\sum w}$
varargin can be dim
function [mu serr] = nanwmean(w,x)

127.31 nanwstd

weighed standard deviation

127.32 nanwvar

weighted variance of columns, corrected for degrees of freedom (bessel)

$$s^2 = \frac{\sum (w * (x - \frac{\sum wx}{\sum w})^2)}{\sum w}$$

127.33 nanxcorr

127.34 pearson

pearson correlation coefficient

127.35 pearson_to_kendall

conversion of pearson to kendall correlation coefficient
c.f. Kruskal 1958

127.36 pool_samples

pooled mean and standard deviation of several groups of different
size, mean and standard deviation

127.37 qmean

trimmed mean

127.38 range_mean

127.39 rmse_

root mean square error computed from a residual vector
this is de-facto the std for an unbiased residual

127.40 serr

standard error of the mean of a set of uncorrelated samples

127.41 serr1

127.42 test_kskew

127.43 test_qstd_kskew_optimal_p

127.44 wautocorr

autocorrelation for x if x is a vector, or individually for the columns of x if x is a matrix
samples can be weighted

c.f. box_jenkins 2008 eq. 2.1.12

c.f. autocorr_man4

Note that it is faster to compute the acf in frequency space as done in the matlab internal function

127.45 wcorr

correlation of two vectors when samples are weighted

127.46 wcov

covariance of two vectors when samples are weighted

127.47 wdof

effective degrees of freedom for weighted samples

127.48 wkurt

kurtosis with weighted samples

127.49 wmean

weighted mean

$\min_x \sum w (x - \mu)^2 \Rightarrow \mu = \frac{\sum wx}{\sum w}$

varargin can be dim

function [mu serr] = wmean(w,x)

127.50 wrms

weighted root mean square

127.51 wserr

weighted root mean square error

127.52 wskew

skewness of a weighted set of samples

function sk = wskew(w,x)

127.53 wstd

weighed standard deviation

127.54 wvar

weighted variance of columns, corrected for degrees of freedom (bessel)

variance of the weighted sample mean of samples with same mean (but not necessarily same variance)

$s^2 = \frac{\sum w^2 (x - \frac{\sum wx}{\sum w})^2}{\sum w}$

s2_mu : error of mean, s2_mu : sd of prediction

128 statistics

128.1 nangeomean

128.2 nangeostd

geometric standard deviation ignoring nan-values

129 statistics/nonparametric-statistics

129.1 kernel1d

`X` : ouput x axis bins
`xi` : samples along x
`m` : number of bins in `X`
`fun` : kernel function
`pdf` : propability density of `xi`

129.2 kernel2d

kernel density estimate in two dimensions

130 statistics

130.1 normalize_exponential_random_variable

130.2 normmmoment

expected norm of $x.^n$, when values `x` in `x` are iid normal with `mu`
and `sigma`

130.3 normpdf2

pdf of the bivariate normal distribution

131 statistics/order-statistics

131.1 hodges_lehmann_location

hodges lehman location estimator

Asymptotic rms efficiency of location estimate:

mean: $1 s/\sqrt{n}$

hodges lehman: $\sqrt{\pi/3} * s \sim 1.0233 s/\sqrt{n}$

median: $\pi/2 s/\sqrt{n} \sim 1.25 s / \sqrt{n}$

131.2 kendall

kendall correlation coefficient

131.3 kendall_to_pearson

convert kendall rank correlation coefficient to the person product
moment

correlation coefficient

c.f. Kruskal, 1958, p. 823

131.4 mad2sd

transform median absolute deviation to standard deviation
for normal distributed values

131.5 madcorr

proxy correlation by median absolute deviation

131.6 median2_holder

131.7 median_ci

median and its confidence intervals under assumption of normality
`se_me = sqrt(1/2 pi) 1.25331 * sd/sqrt(n)`

131.8 median_man

median and confidence intervals
`c` is a P value for the confidence interval,
default is 0.95 (2-sigma)
median of the columns of `X`

131.9 mediani

index of median, if median is not unique, any of the values is
chosen

131.10 nanmadcorr

proxy correlation by median absolute deviation

131.11 nanwmedian

weighted median, skips nan-values

131.12 nanwquantile

weighted quantile, skips nan values

131.13 oja_median

two dimensional oja median

note: the multivariate median is not unique

oja 1983, for extension to multivariate function, see chaudhri

131.14 qkurtosis

kurtosis computed for quantiles

Note : this is a measurement of shape-tailedness and yields the same value for the

normal distribution as "kurtosis"

However, this is a separate statistic and hence requires different

methods for calculating P-values and hypothesis testing

131.15 qmoments

moments estimated from quantiles

131.16 qskew

skewness estimated from quantiles

Note : this is a measurement of shape-symmetry and yields the same value for the

skew-normal distribution as "skewness"

However, this is an own statistic and hence requires different

methods for calculating P-values and hypothesis testing

131.17 qskewq

skewness estimated by quantiles

131.18 qstdq

proxy standard deviation determined by quantiles

131.19 quantile1_optimisation

131.20 quantile2_breckling

qunatile regression

131.21 quantile2_chaudhuri

quantile regression

131.22 quantile2_projected

quantile in two dimensions

131.23 quantile2_projected2

spatial qunatile for chosen direction

131.24 quantile_envelope

131.25 quantile_regression_simple

simple quantile regression

131.26 ranking

ranking for spearman statistics

131.27 spatial_median

c.f. Oja 2008

is this the same as the oja simplex median (c.f. small 1990)?

131.28 spatial_quantile

spatial quantile

131.29 spatial_quantile2

spatial quantile

131.30 spatial_quantile3

spatial quantile

131.31 spatial_rank

unsigned rank

131.32 spatial_sign

spatial sign

131.33 spatial_signed_rank

signed rank

Note: this is only a true rank if X is normal with zero mean,
arbitrary variance

131.34 spearman

spearman's product moment coefficient

131.35 spearman_rank

131.36 spearman_to_pearson

conversion of spearman rank to person product moment correlation coefficient

131.37 wmedian

weighted median

131.38 wquantile

weighted quantile

132 statistics

132.1 qstd

132.2 quantile_extrap

132.3 quantile_sin

133 statistics/random-number-generation

133.1 laplacernd

random number of laplace distribution

133.2 randc

correlate to correlated standard normally distributed vectors

133.3 skewness2param

133.4 skewpdf_central_moments

133.5 skewrnd

random numbers of the skew normal distribution

134 statistics

134.1 range

range and mid range of input

134.2 resample_with_replacement

135 statistics/resampling-statistics/@Jackknife

135.1 Jackknife

class for leave out 1 (delete 1) Jackknife estimates

note 1 : the 1-delete jackknife does not yield consistend estimates
for all functions,
in particular it will perform poorly on robust estimation
functions
this is overcome by the d-delete jackknife, where d has to
exceed the breakdown point
of the estimating function, for example \sqrt{n} for the
median
as this leads to unreasonably large number of repetitions,
bootstrap
is recommended for large sample cases (or blocking for
sequential data)
note 2 : as a linearisation, jackknife underestimates the error
variance in case of
dependence in the data
note 3 : studentisation and the leave out 1 jackknife are related
note 4 : the double 1 sample jackknife performs iferior to the d1
jackknife

135.2 estimated_STATIC

jackknife estimate of mean, bias and standard error
theta0 : estimate from all samples
thetad : set of estimates obtained by leaving out one data point
each
last dimension of theta is assumed to be the jackknife
dimension

135.3 matrix1_STATIC

matrix of estimation for leaving out two samples at a time

135.4 matrix2

matrix of estimations for jacknive with two samples left out

136 statistics/resampling-statistics

136.1 block_jackknife

136.2 jackknife_moments

moments determined by the jackknife

func : function of interest on the samples (e.g. mean)
A : parameter matrix
 columns : parameters
 rows : samples of the parameter sets
d : number of samples left out

136.3 moving_block_jackknife

blocked Jackknife for autocorrelated data
sliding block, statistically more efficient but computationally
expensive
note, number of blocks must be sufficiently large $h \sim \sqrt{n}$? $\ll n$

136.4 randblockterr

standard error of sequentially correlated data by blocking
block length should be sufficiently larger than correlation length
and sufficiently smaller than data length
this uses a sliding block approach, which reduces the variation of
the error estimate
TODO this does not work, randomly picking samples does not reveal
the correlation

136.5 resample

resample a vector and apply function to it

TODO, should be with replacement

n : number of samples

m : number of subsamples
cx : maximum number of combinations

137 statistics

137.1 scale_quantile_sd

scale factor for the standard deviation
of the asymptotic distribution of sample quantiles
(for normal distribution)
see cadwell, 1952

137.2 sd_sample_quantiles

137.3 spatialrnd

137.4 trimmed_mean

trimmed mean

137.5 ttest2_man

two-sample t-test
here posix return value standard: h = 0 accepted, h = 1 failed
note: the matlab logic is inverse : h = 1 accepted, h = 0 failed
two sided univariate t-test

137.6 ttest_man

two-sample t-test
unequal sample size
equal variance

137.7 `ttest_paired`

paired t-test
unequal sample size
equal variance
more powerfull than unpaired test, as long as correlation between
 x_1 and $x_2 > 0$

137.8 `uniformnpdf`

137.9 `wgeomean`

weighted geometric mean
function `mu = wgeomean(w,x)`

137.10 `wgeovar`

variance of the weighted geometric mean

137.11 `wharmean`

weighted harmonic mean

137.12 `wharstd`

137.13 `wharvar`

138 stochastic

138.1 `brownian_drift_hitting_probability`

138.2 brownian_drift_hitting_probability2

138.3 brownian_field

```
simulate Fractional Brownian field on unit disk, with Hurst
    parameter 'H';
Reference:
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

138.4 brownian_field_scaled

```
generate a square (fractal brownian) field where the variance is
    ellyptic,
i.e. increasing at different rates in both axes
this is facilitated by cropping and stretching
TODO can the kernel directly be adapted?
```

138.5 brownian_motion_1d_acf

138.6 brownian_motion_1d_cov

138.7 brownian_motion_1d_fft

138.8 brownian_motion_1d_fourier

138.9 brownian_motion_1d_interleave

138.10 brownian_motion_1d_laplacian

138.11 brownian_motion_2d_cov

138.12 brownian_motion_2d_fft

138.13 brownian_motion_2d_fft_old

138.14 brownian_motion_2d_fourier

138.15 brownian_motion_2d_interleave

138.16 brownian_motion_2d_interleaving

138.17 brownian_motion_2d_kahunen

138.18 brownian_motion_2d_laplacian

138.19 brownian_motion_with_drift_hitting_probability

139 stochastic/geometric-ar1

139.1 geometric_ar1_2d_generate

139.2 geometric_ar1_2d_generate_1

realization of the spatial geometric ornstein (geometric ar1)
process
averaged over grid cells

139.3 geometric_ar1_2d_grid_cell_averaged_cov

139.4 geometric_ar1_2d_grid_cell_averaged_generate

simulate a grid cell averaged stochastic process $\exp(z)$
where z follows an Ornstein-Uhlenbeck (AR1) process
with mean lmu , standard deviation sd and stationary autocorrelation
 $\text{corr}(z(0,0), z(x,y)) = \exp(-\sqrt{x^2 + y^2}/\text{theta})$

139.5 geometric_ar1_2d_grid_cell_averaged_moment2par

139.6 geometric_ar1_2d_grid_cell_averaged_std

mean of the values val
covariance function of the values

140 stochastic

140.1 ornstein_uhlenbeck_cov

140.2 `ornstein_uhlenbeck_mean`

140.3 `ornstein_uhlenbeck_spectral_density`

140.4 `ornstein_uhlenbeck_std`

141 `mathematics`

mathematical functions of various kind

141.1 `ternary_diagram`

142 `test/finance`

142.1 `test_gbb_mean`

142.2 `test_gbb_std`

142.3 `test_gbm_mean`

142.4 `test_gbm_mean_entire_series`

142.5 test_gbm_moment2par

142.6 test_gbm_moment2par_entire_series

142.7 test_gbm_std

142.8 test_gbm_std_entire_series

143 test/fourier

143.1 test_fourier_freq2ind

144 test/master

144.1 dat_test_lanczos_3d_k_20_n_40

144.2 poisson2d_blk

144.3 qr_implicit_givens_2

144.4 spectral_derivative_2d

144.5 test_2d_eigensolver_hydrogen

144.6 test_2d_refine

144.7 test_3d_eigensolver_hydrogen

144.8 test_FEM

144.9 test_Mesh_3d

144.10 test_arnoldi

144.11 test_arpackc

144.12 test_assemble

144.13 test_assembly_performance

144.14 test_bc_one_sided

144.15 test_compare_solvers

144.16 test_complete

144.17 test_convergence

144.18 test_convergence_b

144.19 test_df_2d

144.20 test_eig_algs

144.21 test_eig_inverse

144.22 test_eigs_lanczos

144.23 test_eigs_lanczos_1

144.24 test_eigs_lanczos_2

144.25 test_eigs_lanczos_performance

144.26 test_fdm

144.27 test_fdm_d_vargrid

144.28 test_fdm_spectral

144.29 test_fem

144.30 test_fem_1d

144.31 test_fem_1d_higher_order

144.32 test_fem_2d_adaptive

144.33 test_fem_2d_higher_order

144.34 test_fem_3d_higher_order

144.35 test_fem_3d_refine

144.36 test_fem_b

144.37 test_fem_derivative

144.38 test_fem_quadrature

144.39 test_final

144.40 test_fix_substitution

144.41 test_forward

144.42 test_get_sparse_arrays

144.43 test_harmonic_oscillator

144.44 test_high_order_fdm_periodic_bc

144.45 test_hydrogen_wf

144.46 test_ichol

144.47 test_interpolation

144.48 test_inverse_problem

144.49 test_it_vs_exact

144.50 test_jama

144.51 test_jd

144.52 test_jdqz

144.53 test_lanczos_2

144.54 test_lanczos_biorthogonal

144.55 test_laplacian

144.56 test_laplacian_non_uniform

144.57 test_laplacian_simple

144.58 test_mesh_2d_uniform

144.59 test_mesh_2d_uniform_2

144.60 test_mesh_circle

144.61 test_mesh_generation

144.62 test_mesh_interpolate

144.63 test_mg

144.64 test_minres_recycle

144.65 test_multigrid

144.66 test_nc

144.67 test_nonuniform_symmetric

144.68 test_pde

144.69 test_permutation

144.70 test_poison_fem

144.71 test_polar

144.72 test_potential

144.73 test_powers

144.74 test_precondition

144.75 test_project_rectangle

144.76 test_qr

144.77 test_quantum_well

144.78 test_radial_adaptive

144.79 test_radial_confinement

144.80 test_radial_fixes

144.81 test_refine_2d

144.82 test_refine_2d_b

144.83 test_refine_3d

144.84 test_refine_structural

144.85 test_regularisation

144.86 test_round_off

144.87 test_schrödinger_potentials

144.88 test_uniform_mesh

144.89 test_vargrid

145 test/numerical-methods/optimisation

145.1 test_extreme3

146 test/signal-processing/autocorrelation

146.1 test_acf

146.2 test_acf_bias

146.3 test_acfar1_2

146.4 test_acfar1_3

146.5 test_acfar1_4

146.6 test_acfar2

146.7 test_ar1_var_factor

146.8 test_ar1_var_factor_2

146.9 test_ar1_var_mu_single_sample

146.10 test_ar1_var_pop

146.11 test_ar1_var_pop_1

146.12 test_ar1delay

146.13 test_ar2

146.14 test_phase_drift_acf

147 test/signal-processing/passes

147.1 test_bandpass2d

147.2 test_bandpass2d_ideal

147.3 test_lowpass1d_fft

147.4 test_lowpass1d_implicit

147.5 test_lowpass2d_anisotropic

147.6 test_lowpass2d_fft

147.7 test_lowpass2d_rho

148 test/signal-processing/periodogram

148.1 test_periodicity_test_2d

148.2 test_periodogram_bartlett_se

148.3 test_periodogram_gauss

148.4 test_periodogram_radial

148.5 test_periodogram_test

148.6 test_periodogram_test_periodicity_2d

148.7 test_periogogram_significance

149 test/signal-processing/spectral-density

149.1 test_phase_drift_parallel_pdf

149.2 test_phase_drift_parallel_pdf_mode2par

149.3 test_phase_drift_pdf

149.4 test_phase_drift_pdf_2d

149.5 test_phase_drift_pdf_mode

149.6 test_phase_drift_pdf_mode2par

149.7 test_phase_drift_pdf_scale

149.8 test_spectral_density_2

149.9 test_spectral_density_bandpass_2d

149.10 test_spectral_density_bandpass_2d_max2par

149.11 test_spectral_density_bandpass_continuous

```
title(sprintf('n %d L %g %g%%',[n,L,1e2*rmse(idx,jdx)]));
```

149.12 test_spectral_density_bandpass_continuous_1

149.13 test_spectral_density_bandpass_maximum

- 149.14 `test_spectral_density_bandpass_scale`
- 149.15 `test_spectral_density_bp`
- 149.16 `test_spectral_density_bp_2d`
- 149.17 `test_spectral_density_bp_approx`
- 149.18 `test_spectral_density_flat`
- 149.19 `test_spectral_density_hp_cos`
- 149.20 `test_spectral_density_lorentzian_max`
- 149.21 `test_spectral_density_lorentzian_scale`
- 149.22 `test_spectral_density_lowpass`
- 149.23 `test_spectral_density_lowpass_continuous`

149.24 test_spectral_density_lowpass_continuous_1

149.25 test_spectral_density_maxiumum_bias_corrected

150 test/signal-processing

150.1 test_autocorrelation_max

150.2 test_cdf_bandpass_continuous

150.3 test_fit_spectral_density

150.4 test_phase_drift_cdf

151 test/spatial-pattern-analysis

151.1 test_approximate_ratio_distribution

151.2 test_approximate_ratio_quantile

151.3 test_separate_isotropic_density

152 test/spatial-statistics

152.1 test_cov_cell_averages_1d

152.2 test_cov_cell_averages_2d

153 test/statistics/distributions/anisotropic

153.1 test_anisotropic_pattern

153.2 test_anisotropic_pattern_pdf

154 test/statistics/distributions/gamma

154.1 test_generalized_gamma_mean

155 test/statistics/distributions/log-uniform

155.1 test_logurnd

156 test/statistics/distributions/lognormal

156.1 test_logn_cov

157 test/statistics/distributions/mises

157.1 test_mises_std

158 test/statistics/distributions/passes

158.1 test_bandpass2d_pdf

158.2 test_bandpass2d_pdf_hankel

158.3 test_bandpass2d_pdf_mode

158.4 test_lowpass2d_pdf_hankel

158.5 test_lowpass2d_pdf_series

159 test/statistics/distributions/skew-normal

159.1 test_skew_generalized_normpdf

160 test/statistics/distributions

160.1 test_normpdf_wrapped

161 **test/statistics/distributions/weibull**

161.1 test_wbl_std

162 **test/statistics/moment-statistics**

162.1 test_wmean

163 **test/statistics**

163.1 test_fisher_moment2par

163.2 test_gamma_mode

163.3 test_normalize_exponential_random_variable

164 **test/stochastic**

164.1 test_brownian_field

164.2 test_brownian_field_scaled

165 **test/stochastics**

165.1 test_brownian_surface

166 test

166.1 test_S

166.2 test_advect_analytic

166.3 test_asymbp

166.4 test_bandwidth

166.5 test_bartlett_angle

166.6 test_bartlett_distribution

166.7 test_bartlett_expansion

166.8 test_beta

166.9 test_betainc

166.10 test_bivariate_covariance_term

166.11 test_brownian_drift_hitting_probability

166.12 test_brownian_drift_hitting_probability2

166.13 test_brownian_motion_1d

166.14 test_brownian_motion_2d_cov

166.15 test_brownian_motion_2d_fft

166.16 test_brownian_noise_1d

166.17 test_brownian_noise_2d

166.18 test_brownian_noise_interleave

166.19 test_coherence

166.20 test_combined_spectral_density

166.21 test_continuous_fourier_transform

166.22 test_convexity

166.23 test_d2

166.24 test_determine_phase_shift

166.25 test_diffuse_analytic

166.26 test_diffusion_matrix

166.27 test_ellipse

166.28 test_error_propagation_fraction

166.29 test_f

166.30 test_f2

166.31 test_fit_2d_spectral_density

166.32 test_fourier

166.33 test_fourier_derivative

166.34 test_fourier_derivative_1

166.35 test_fourier_integral

166.36 test_fourier_mask_covariance_matrix

166.37 test_ft_bp

166.38 test_gam

166.39 test_gamma_distribution

166.40 test_gampdf_man

166.41 test_gaussfit3

166.42 test_gaussian_flat

166.43 test_geoserr

166.44 test_hexagonal_pattern

166.45 test_iafrate

166.46 test_implicit_ode

166.47 test_imrotmat

166.48 test_integration

166.49 test_ivp

166.50 test_jacobian

166.51 test_lanczoswin

166.52 test_laplacian_power

166.53 test_lognfit_quantile

166.54 test_ls_perpendicular_offset

166.55 test_madcorr

166.56 test_mask

166.57 test_max_normal

166.58 test_moments

166.59 test_moments_fourier_power

166.60 test_mtimes3x3

166.61 test_noisy_oscillator

166.62 test_nonperiodic_pattern

166.63 test_normaliztation

166.64 test_ols

166.65 test_parcorr

166.66 test_positivity_preserving

166.67 test_randar1

166.68 test_randar1_multivariate

166.69 test_randar2

166.70 test_ratio_distributions

166.71 test_sd_rectwin

166.72 test_spatialrnd

166.73 test_spectrum_additivity

166.74 test_stationarity

166.75 test_stationarity2

166.76 test_sum_ij

166.77 test_sum_multivar

166.78 test_trifilt1

166.79 test_wautocorr

166.80 test_wavelet_transform

166.81 test_whittle

166.82 test_window

166.83 test_wordfilt

166.84 test_xar1_mid_term

167 mathematics

mathematical functions of various kind

167.1 trapezoidal_fixed

168 wavelet

168.1 continuous_wavelet_transform

continuous wavelet transform

follows "The Illustrated Wavelet Transform Handbook: Introductory
Theory and ..."

168.2 cwt_man

continuous fourier transform
as of time of implmentation, the matlab interal cwt is affected by
serious round-off errors and has issues with the scaling,
which is not the case here

168.3 cwt_man2

168.4 example_wavelets

168.5 phasewrap

wrap the phase to +/- pi

168.6 test_cwt_man

168.7 test_phasewrap

168.8 test_wavelet

168.9 test_wavelet2

168.10 test_wavelet_analysis

168.11 test_wavelet_reconstruct

168.12 test_wtc

168.13 wavelet

wavelet windows

168.14 wavelet_reconstruct

inverse wavelet transform for single frequency
(reconstruction of time series)
n : window lengths in multiples of filter period $1/f_0$

168.15 wavelet_transform

wavelet transform for single frequency
n : window lengths in multiples of filter period $1/f_0$