Package 'qtsa'

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Title Quantum Time Series Analysis: Drift, Noise Spectroscopy and Calibration Forecasting

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Description Tools for exploratory statistical analysis of quantum-hardware calibration time series. The package provides simulators for random telegraph noise (RTN), power-law noise, and Ornstein-Uhlenbeck dephasing; Welch and sine-multitaper power spectral density estimators; a lightweight two-state hidden Markov model for switching signals; cumulative sum (CUSUM) and binary-segmentation diagnostics for calibration drift; residual-quantile interval forecasts; and filter-function calculations for illustrative coherence curves. The package includes a reproducible generator of simulated superconducting-qubit calibration records; it does not retrieve authenticated live provider data. Methodological background is provided by Welch (1967) <doi:10.1109/TAU.1967.1161901>, Thomson (1982) <doi:10.1109/PROC.1982.12433>, Rabiner (1989) <doi:10.1109/5.18626>, Page (1954) <doi:10.1093/biomet/41.1-2.100>, Paladino et al. (2014) <doi:10.1103/RevModPhys.86.361>, and Cywinski et al. (2008) <doi:10.1103/PhysRevB.77.174509>.

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Contents

`compute_Wt` *Compute an illustrative coherence value from a PSD*

Description

Part of the qtsa toolkit for exploratory analysis of quantum-hardware calibration time series.

Usage

```
compute_Wt(psd, filter)
```

Arguments

`psd`	data frame with f and S columns
`filter`	output from filter_function_q

Details

This function is intended for exploratory analysis. Interpret physically meaningful results only after checking sampling frequency, units, and model assumptions.

Value

A list with chi, W, interpolated spectrum, filter values, and frequency.

Author(s)

Leila Marvian Mashhad

Examples

```
x <- rnorm(100)
# See the package vignette or help pages for a complete workflow.
```

`cp_qdrift` *Binary-segmentation drift diagnostic*

Description

Part of the qtsa toolkit for exploratory analysis of quantum-hardware calibration time series.

Usage

```
cp_qdrift(x, pen = NULL, min_seg = 20)
```

Arguments

`x`	numeric time series
`pen`	penalty for adding a changepoint
`min_seg`	minimum segment length

Details

This function is intended for exploratory analysis. Interpret physically meaningful results only after checking sampling frequency, units, and model assumptions.

Value

A list with changepoints, segment means, and the number of segments.

Author(s)

Leila Marvian Mashhad

Examples

```
x <- rnorm(100)
# See the package vignette or help pages for a complete workflow.
```

cusum_q *CUSUM drift diagnostic*

Description

Part of the qtsa toolkit for exploratory analysis of quantum-hardware calibration time series.

Usage

```
cusum_q(x, target = NULL, k = NULL, h = NULL, sigma = NULL)
```

Arguments

x	numeric time series
target	in-control target mean; default uses early observations
k	reference value
h	decision interval
sigma	in-control standard deviation

Details

This function is intended for exploratory analysis. Interpret physically meaningful results only after checking sampling frequency, units, and model assumptions.

Value

A list containing CUSUM paths, parameter values, and alarm indices.

Author(s)

Leila Marvian Mashhad

Examples

```
x <- rnorm(100)
# See the package vignette or help pages for a complete workflow.
```

decoherence_curve *Compute an illustrative decoherence curve*

Description

Part of the qtsa toolkit for exploratory analysis of quantum-hardware calibration time series.

Usage

```
decoherence_curve(psd, t_grid = seq(0.1, 10, length.out = 100), n_pulses = 1)
```

Arguments

psd	data frame with f and S columns
t_grid	times at which to evaluate coherence
n_pulses	number of idealized pi pulses

Details

This function is intended for exploratory analysis. Interpret physically meaningful results only after checking sampling frequency, units, and model assumptions.

Value

A data frame with t, W, and chi.

Author(s)

Leila Marvian Mashhad

Examples

```
x <- rnorm(100)
# See the package vignette or help pages for a complete workflow.
```

estimate_rtn_hmm *Estimate a two-state switching model*

Description

Part of the qtsa toolkit for exploratory analysis of quantum-hardware calibration time series.

Usage

```
estimate_rtn_hmm(x, n_states = 2, max_iter = 50, seed = NULL)
```

Arguments

x	numeric time series
n_states	number of states; the implementation is intended for two states
max_iter	maximum number of hard-EM refinement iterations
seed	optional random-number seed for k-means initialization; NULL leaves the current random-number stream unchanged

Details

This function is intended for exploratory analysis. Interpret physically meaningful results only after checking sampling frequency, units, and model assumptions.

Value

A list containing state means, standard deviations, transition matrix, decoded states, dwell summaries, and amplitude.

Author(s)

Leila Marvian Mashhad

Examples

```
x <- rnorm(100)
# See the package vignette or help pages for a complete workflow.
```

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fetch_ibm_calib *Generate simulated IBM-like calibration data*

Description

Part of the qtsa toolkit for exploratory analysis of quantum-hardware calibration time series.

Usage

```
fetch_ibm_calib(n = 500, backend = "ibmq_manila_sim", seed = NULL, simulate = TRUE)
```

Arguments

n	number of time points
backend	label included in the output; no network request is made
seed	optional random-number seed; NULL leaves the current random-number stream unchanged
simulate	retained for backward compatibility; only simulated data are produced

Details

This function is intended for exploratory analysis. Interpret physically meaningful results only after checking sampling frequency, units, and model assumptions.

Value

A data frame with time, backend, T1, T2, freq_GHz, and readout_err columns.

Author(s)

Leila Marvian Mashhad

Examples

```
x <- rnorm(100)
# See the package vignette or help pages for a complete workflow.
```

`fidelity_ts` *Compute a simple fidelity proxy*

Description

Part of the qtsa toolkit for exploratory analysis of quantum-hardware calibration time series.

Usage

```
fidelity_ts(T1, T2, gate_time = 0.05)
```

Arguments

`T1`	numeric relaxation-time series
`T2`	numeric dephasing-time series
`gate_time`	gate duration in the same time units as T1 and T2

Details

This function is intended for exploratory analysis. Interpret physically meaningful results only after checking sampling frequency, units, and model assumptions.

Value

A numeric vector of bounded fidelity-proxy values.

Author(s)

Leila Marvian Mashhad

Examples

```
x <- rnorm(100)
# See the package vignette or help pages for a complete workflow.
```

`filter_function_q` *Construct a simple dynamical-decoupling filter function*

Description

Part of the qtsa toolkit for exploratory analysis of quantum-hardware calibration time series.

Usage

```
filter_function_q(t, n_pulses = 1, f, dt = NULL)
```

Arguments

`t`	total evolution time
`n_pulses`	number of idealized pi pulses
`f`	numeric frequency vector
`dt`	reserved time-resolution argument

Details

This function is intended for exploratory analysis. Interpret physically meaningful results only after checking sampling frequency, units, and model assumptions.

Value

A list with frequency, angular frequency, filter values, time, and pulse count.

Author(s)

Leila Marvian Mashhad

Examples

```
x <- rnorm(100)
# See the package vignette or help pages for a complete workflow.
```

`forecast_calib` *Rolling residual interval forecast*

Description

Part of the qtsa toolkit for exploratory analysis of quantum-hardware calibration time series.

Usage

```
forecast_calib(x, h = 20, window = 100, alpha = 0.1, method = "ets")
```

Arguments

`x`	numeric time series
`h`	forecast horizon
`window`	length of the rolling training window
`alpha`	nominal miscoverage level used for the residual quantile
`method`	one of "mean", "ets", or "arima"; the current implementation uses lightweight baseline forecasts

Details

This function is intended for exploratory analysis. Interpret physically meaningful results only after checking sampling frequency, units, and model assumptions.

Value

A list with point forecast, lower and upper interval limits, residuals, and residual quantile.

Author(s)

Leila Marvian Mashhad

Examples

```
x <- rnorm(100)
# See the package vignette or help pages for a complete workflow.
```

`forecast_T1` *Alias for forecast_calib*

Description

Part of the qtsa toolkit for exploratory analysis of quantum-hardware calibration time series.

Usage

```
forecast_T1(x, h = 20, window = 100, alpha = 0.1, method = "ets")
```

Arguments

`x`	numeric T1 series
`h`	forecast horizon
`window`	rolling window length
`alpha`	nominal miscoverage level
`method`	forecast method

Details

This function is intended for exploratory analysis. Interpret physically meaningful results only after checking sampling frequency, units, and model assumptions.

Value

A list returned by forecast_calib.

Author(s)

Leila Marvian Mashhad

Examples

```
x <- rnorm(100)
# See the package vignette or help pages for a complete workflow.
```

`hmm_rtn_fit` *Alias for estimate_rtn_hmm*

Description

Part of the qtsa toolkit for exploratory analysis of quantum-hardware calibration time series.

Usage

```
hmm_rtn_fit(x, n_states = 2, max_iter = 50, seed = NULL)
```

Arguments

`x`	numeric time series
`n_states`	number of states
`max_iter`	maximum number of iterations
`seed`	optional random-number seed for k-means initialization; `NULL` leaves the current random-number stream unchanged

Details

This function is intended for exploratory analysis. Interpret physically meaningful results only after checking sampling frequency, units, and model assumptions.

Value

A list returned by estimate_rtn_hmm.

Author(s)

Leila Marvian Mashhad

Examples

```
x <- rnorm(100)
# See the package vignette or help pages for a complete workflow.
```

plot_drift *Plot calibration drift diagnostics*

Description

Part of the qtsa toolkit for exploratory analysis of quantum-hardware calibration time series.

Usage

```
plot_drift(x, metric = "T1", ...)
```

Arguments

x	data frame returned by fetch_ibm_calib or a numeric series
metric	column to plot when x is a data frame
...	additional arguments reserved for future use

Details

This function is intended for exploratory analysis. Interpret physically meaningful results only after checking sampling frequency, units, and model assumptions.

Value

Invisibly, a list containing CUSUM and changepoint diagnostics.

Author(s)

Leila Marvian Mashhad

Examples

```
x <- rnorm(100)
# See the package vignette or help pages for a complete workflow.
```

psd_mtm_q *Alias for psd_multitaper_q*

Description

Part of the qtsa toolkit for exploratory analysis of quantum-hardware calibration time series.

Usage

```
psd_mtm_q(x, fs = 1, nw = 3, k = 5)
```

Arguments

x	numeric time series
fs	sampling frequency in Hz
nw	nominal time-bandwidth parameter
k	number of sine tapers

Details

This function is intended for exploratory analysis. Interpret physically meaningful results only after checking sampling frequency, units, and model assumptions.

Value

A data frame with f, S, S_low, and S_high.

Author(s)

Leila Marvian Mashhad

Examples

```
x <- rnorm(100)
# See the package vignette or help pages for a complete workflow.
```

---

psd_multitaper_q *Sine-multitaper power spectral density estimator*

Description

Part of the qtsa toolkit for exploratory analysis of quantum-hardware calibration time series.

Usage

```
psd_multitaper_q(x, fs = 1, nw = 3, k = 5)
```

Arguments

x	numeric time series
fs	sampling frequency in Hz
nw	nominal time-bandwidth parameter used to choose a conventional taper count
k	number of sine tapers

Details

This function is intended for exploratory analysis. Interpret physically meaningful results only after checking sampling frequency, units, and model assumptions.

Value

A data frame with f, S, S_low, and S_high.

Author(s)

Leila Marvian Mashhad

Examples

```
x <- rnorm(100)
# See the package vignette or help pages for a complete workflow.
```

`psd_welch` *Welch power spectral density estimator*

Description

Part of the qtsa toolkit for exploratory analysis of quantum-hardware calibration time series.

Usage

```
psd_welch(x, fs = 1, nperseg = 256, noverlap = NULL, window = "hann")
```

Arguments

`x`	numeric time series
`fs`	sampling frequency in Hz
`nperseg`	segment length
`noverlap`	number of overlapping observations
`window`	window type; currently "hann" is supported

Details

This function is intended for exploratory analysis. Interpret physically meaningful results only after checking sampling frequency, units, and model assumptions.

Value

A data frame with frequency f and one-sided spectral density S.

Author(s)

Leila Marvian Mashhad

Examples

```
x <- rnorm(100)
# See the package vignette or help pages for a complete workflow.
```

`r_oneoverf` *Power-law noise simulator*

Description

Part of the qtsa toolkit for exploratory analysis of quantum-hardware calibration time series.

Usage

```
r_oneoverf(n, alpha = 1, fs = 1, f_low = NULL)
```

Arguments

`n`	positive number of samples
`alpha`	power-law exponent
`fs`	sampling frequency in Hz
`f_low`	optional low-frequency cutoff

Details

This function is intended for exploratory analysis. Interpret physically meaningful results only after checking sampling frequency, units, and model assumptions.

Value

A list with time vector, simulated signal, sampling frequency, and exponent.

Author(s)

Leila Marvian Mashhad

Examples

```
x <- rnorm(100)
# See the package vignette or help pages for a complete workflow.
```

`r_ou_dephasing` *Ornstein-Uhlenbeck dephasing simulator*

Description

Part of the qtsa toolkit for exploratory analysis of quantum-hardware calibration time series.

Usage

```
r_ou_dephasing(n, tau_c = 10, sigma = 1, dt = 1)
```

Arguments

`n`	positive number of samples
`tau_c`	correlation time
`sigma`	stationary standard deviation
`dt`	time increment

Details

This function is intended for exploratory analysis. Interpret physically meaningful results only after checking sampling frequency, units, and model assumptions.

Value

A numeric vector containing a simulated process.

Author(s)

Leila Marvian Mashhad

Examples

```
x <- rnorm(100)
# See the package vignette or help pages for a complete workflow.
```

`r_rtn` *Random Telegraph Noise simulator*

Description

Part of the qtsa toolkit for exploratory analysis of quantum-hardware calibration time series.

Usage

```
r_rtn(n, fs = 1, amplitude = 1, tau_up = 50, tau_down = 50, p0 = 0.5)
```

Arguments

`n`	positive number of samples
`fs`	sampling frequency in Hz
`amplitude`	difference between the two signal levels
`tau_up`	mean dwell time in the upper state, in samples
`tau_down`	mean dwell time in the lower state, in samples
`p0`	probability of starting in the upper state

Details

This function is intended for exploratory analysis. Interpret physically meaningful results only after checking sampling frequency, units, and model assumptions.

Value

A numeric vector containing the simulated RTN signal.

Author(s)

Leila Marvian Mashhad

Examples

```
set.seed(1)
x <- r_rtn(100)
head(x)
```

`viterbi_rtn` *Viterbi decoder for a switching model*

Description

Part of the qtsa toolkit for exploratory analysis of quantum-hardware calibration time series.

Usage

```
viterbi_rtn(log_emission, log_trans)
```

Arguments

`log_emission`	matrix of log emission probabilities with observations in rows
`log_trans`	matrix of log transition probabilities

Details

This function is intended for exploratory analysis. Interpret physically meaningful results only after checking sampling frequency, units, and model assumptions.

Value

An integer vector giving the most likely state path.

Author(s)

Leila Marvian Mashhad

Examples

```
x <- rnorm(100)
# See the package vignette or help pages for a complete workflow.
```

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