Package 'hermiter'

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Title Efficient Sequential and Batch Estimation of Univariate and Bivariate Probability Density Functions and Cumulative Distribution Functions along with Quantiles (Univariate) and Spearman's Correlation (Bivariate)

Version 2.1.0

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Description Facilitates estimation of full univariate and bivariate probability density functions and cumulative distribution functions along with full quantile functions (univariate) and nonparametric correlation (bivariate) using Hermite series based estimators. These estimators are particularly useful in the sequential setting (both stationary and non-stationary) and one-pass batch estimation setting for large data sets. Based on: Stephanou, Michael, Varughese, Melvin and Macdonald, Iain. ``Sequential quantiles via Hermite series density estimation.'' Electronic Journal of Statistics 11.1 (2017): 570-607 <doi:10.1214/17-EJS1245>, Stephanou, Michael and Varughese, Melvin. ``On the properties of Hermite series based distribution function estimators.'' Metrika (2020) <doi:10.1007/s00184-020-00785-z> and Stephanou, Michael and Varughese, Melvin. ``Sequential estimation of Spearman rank correlation using Hermite series estimators.'' Journal of Multivariate Analysis (2021) <doi:10.1016/j.jmva.2021.104783>.

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`hermiter-package` *Efficient Sequential and Batch Estimation of Univariate and Bivariate Probability Density Functions and Cumulative Distribution Functions along with Quantiles (Univariate) and Spearman's Correlation (Bivariate)*

Description

Facilitates estimation of full univariate and bivariate probability density functions and cumulative distribution functions along with full quantile functions (univariate) and nonparametric correlation (bivariate) using Hermite series based estimators. These estimators are particularly useful in the sequential setting (both stationary and non-stationary) and one-pass batch estimation setting for large data sets. Based on: Stephanou, Michael, Varughese, Melvin and Macdonald, Iain. "Sequential quantiles via Hermite series density estimation." Electronic Journal of Statistics 11.1 (2017): 570-607 <doi:10.1214/17-EJS1245>, Stephanou, Michael and Varughese, Melvin. "On the properties of Hermite series based distribution function estimators." Metrika (2020) <doi:10.1007/s00184-020-00785-z> and Stephanou, Michael and Varughese, Melvin. "Sequential estimation of Spearman rank correlation using Hermite series estimators." Journal of Multivariate Analysis (2021) <doi:10.1016/j.jmva.2021.104783>.

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```

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Author(s)

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`cum_prob` *Estimates the cumulative probability at one or more x values*

Description

This method calculates the cumulative probability at a vector of x values in the univariate case. In the bivariate case, the method calculates the probability density values for a matrix of x values, each row of which represents a 2-d point.

Usage

```
cum_prob(this, x, clipped, accelerate_series = TRUE)
```

Arguments

this	A hermite_estimator_univar or hermite_estimator_bivar object.
x	A numeric vector (univariate) or a numeric matrix (bivariate). Values at which to calculate the cumulative probability.
clipped	A boolean value. This value determines whether cumulative probabilities are clipped to lie between 0 and 1.
accelerate_series	A boolean value. This value determines whether Hermite series acceleration is applied.

Details

The object must be updated with observations prior to the use of the method.

Value

A numeric vector of cumulative probability values.

Examples

```
hermite_est <- hermite_estimator(N = 10, standardize = TRUE,
est_type="univariate")
hermite_est <- update_batch(hermite_est, rnorm(30))
cdf_est <- cum_prob(hermite_est, c(0, 0.5, 1))
hermite_est <- hermite_estimator(N = 10, standardize = TRUE,
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hermite_est <- update_batch(hermite_est, x = matrix(rnorm(60),
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cdf_est <- cum_prob(hermite_est, matrix(c(0,0,0.5,0.5,1,1),nrow=3,
ncol=2,byrow=TRUE))
```

`cum_prob.hermite_estimator_bivar` *Estimates the cumulative probabilities for a matrix of 2-d x values*

Description

This method calculates the cumulative probability values for a matrix of 2-d x vector values using the hermite_estimator_bivar object (this).

Usage

```
## S3 method for class 'hermite_estimator_bivar'
cum_prob(this, x, clipped = FALSE, accelerate_series = FALSE)
```

Arguments

`this`	A hermite_estimator_bivar object.
`x`	A numeric matrix. Each row corresponds to a 2-d coordinate.
`clipped`	A boolean value. This value determines whether cumulative probabilities are clipped to lie within the range [0,1].
`accelerate_series`	A boolean value. Series acceleration has not yet been implemented for bivariate estimators.

Details

The object must be updated with observations prior to the use of this method.

Value

A numeric vector of cumulative probability values.

Examples

```
hermite_est <- hermite_estimator_bivar(N = 10, standardize = TRUE)
hermite_est <- update_batch(hermite_est, matrix(rnorm(30*2), nrow=30,
ncol=2, byrow = TRUE))
cdf_est <- cum_prob(hermite_est, matrix(c(0, 0, 1, 1, 2, 2), nrow=3, ncol=2,
byrow = TRUE))
```

cum_prob.hermite_estimator_univar *Estimates the cumulative probability for a vector of x values*

Description

This method calculates the cumulative probability values at a vector of x values using the hermite_estimator_univar object (this).

Usage

```
## S3 method for class 'hermite_estimator_univar'
cum_prob(this, x, clipped = FALSE, accelerate_series = TRUE)
```

Arguments

this	A hermite_estimator_univar object.
x	A numeric vector. Values at which to estimate the cumulative probability
clipped	A boolean value. This value determines whether cumulative probabilities are clipped to lie within the range [0,1].
accelerate_series	A boolean value. This value determines whether Hermite series acceleration is applied.

Details

The object must be updated with observations prior to the use of this method.

Value

A numeric vector of cumulative probability values.

Examples

```
hermite_est <- hermite_estimator_univar(N = 10, standardize = TRUE)
hermite_est <- update_batch(hermite_est, rnorm(30))
cdf_est <- cum_prob(hermite_est, c(0, 0.5, 1))
```

dens *Estimates the probability density at one or more x values*

Description

This method calculates the probability density values at a vector of x values in the univariate case. In the bivariate case, the method calculates the probability density values for a matrix of x values, each row of which represents a 2-d point.

Usage

```
dens(this, x, clipped, accelerate_series = TRUE)
```

Arguments

this	A hermite_estimator_univar or hermite_estimator_bivar object.
x	A numeric vector (univariate) or a numeric matrix (bivariate) of values at which to calculate the probability density.
clipped	A boolean value. This value determines whether probability densities are clipped to be bigger than zero.
accelerate_series	A boolean value. This value determines whether Hermite series acceleration is applied.

Details

The object must be updated with observations prior to the use of the method.

Value

A numeric vector of probability density values.

Examples

```
hermite_est <- hermite_estimator(N = 10, standardize = TRUE,
est_type="univariate")
hermite_est <- update_batch(hermite_est, rnorm(30))
pdf_est <- dens(hermite_est, c(0, 0.5, 1))
hermite_est <- hermite_estimator(N = 10, standardize = TRUE,
est_type="bivariate")
hermite_est <- update_batch(hermite_est, x = matrix(rnorm(60),
nrow=30, ncol=2,byrow=TRUE))
pdf_est <- dens(hermite_est, matrix(c(0,0,0.5,0.5,1,1),nrow=3,
ncol=2,byrow=TRUE))
```

dens.hermite_estimator_bivar *Estimates the probability densities for a matrix of 2-d x values*

Description

This method calculates the probability density values for a matrix of 2-d x vector values using the hermite_estimator_bivar object (this).

Usage

```
## S3 method for class 'hermite_estimator_bivar'
dens(this, x, clipped = FALSE, accelerate_series = FALSE)
```

Arguments

this	A hermite_estimator_bivar object.
x	A numeric matrix. Each row corresponds to a 2-d coordinate.
clipped	A boolean value. This value determines whether probability densities are clipped to be bigger than zero.
accelerate_series	A boolean value. Series acceleration has not yet been implemented for bivariate estimators.

Details

The object must be updated with observations prior to the use of the method.

Value

A numeric vector of probability density values.

Examples

```
hermite_est <- hermite_estimator_bivar(N = 10, standardize = TRUE)
hermite_est <- update_batch(hermite_est, matrix(rnorm(30*2), nrow=30,
ncol=2, byrow = TRUE))
cdf_est <- dens(hermite_est, matrix(c(0, 0, 1, 1, 2, 2), nrow=3, ncol=2,
byrow = TRUE))
```

`dens.hermite_estimator_univar` *Estimates the probability density for a vector of x values*

Description

This method calculates the probability density values at a vector of x values using the hermite_estimator_univar object (this).

Usage

```
## S3 method for class 'hermite_estimator_univar'
dens(this, x, clipped = FALSE, accelerate_series = TRUE)
```

Arguments

`this`	A hermite_estimator_univar object.
`x`	A numeric vector. Values at which to estimate the probability density.
`clipped`	A boolean value. This value determines whether probability densities are clipped to be bigger than zero.
`accelerate_series`	A boolean value. This value determines whether Hermite series acceleration is applied.

Details

The object must be updated with observations prior to the use of the method.

Value

A numeric vector of probability density values.

Examples

```
hermite_est <- hermite_estimator_univar(N = 10, standardize = TRUE)
hermite_est <- update_batch(hermite_est, rnorm(30))
pdf_est <- dens(hermite_est, c(0, 0.5, 1))
```

gauss_hermite_quad_100 *Calculates $\int$ _$-\infty$^$\infty f(x)e$^$-x^{2}dx$ using Gauss-Hermite quadrature with 100 terms.*

Description

Calculates $\int_{-\infty}^{\infty} f(x)e^{-x^2}dx$ using Gauss-Hermite quadrature with 100 terms.

Usage

```
gauss_hermite_quad_100(f)
```

Arguments

f	A function.

Value

A numeric value.

hermite_estimator *A class to sequentially estimate univariate and bivariate pdfs and cdfs along with quantile functions in the univariate setting and nonparametric correlations in the bivariate setting.*

Description

The hermite_estimator class provides a unified interface to the univariate and bivariate Hermite series based estimators, leveraging generic methods and multiple dispatch. Methods are included for the sequential or one-pass batch estimation of the full probability density function and cumulative distribution function in the univariate and bivariate settings. Sequential or one-pass batch estimation methods are also provided for the full quantile function in the univariate setting and the Spearman's rank correlation estimator in the bivariate setting.

Usage

```
hermite_estimator(
  N = 30,
  standardize = TRUE,
  exp_weight_lambda = NA,
  est_type = "univariate"
)
```

Arguments

N	An integer between 0 and 75. The Hermite series based estimator is truncated at N+1 terms.
standardize	A boolean value. Determines whether the observations are standardized, a transformation which often improves performance.
exp_weight_lambda	A numerical value between 0 and 1. This parameter controls the exponential weighting of the Hermite series based estimator. If this parameter is NA, no exponential weighting is applied.
est_type	A string value. Options are "univariate" or "bivariate".

Value

An S3 object of class hermite_estimator_univar or hermite_estimator_bivar.

Author(s)

Michael Stephanou <michael.stephanou@gmail.com>

Examples

```
hermite_est <- hermite_estimator(N = 30, standardize = TRUE,
est_type="univariate")
```

---

hermite_estimator_bivar

A class to sequentially estimate bivariate pdfs, cdfs and nonparametric correlations

---

Description

This method constructs an S3 object with methods for nonparametric estimation of bivariate pdfs and cdfs along with nonparametric correlations.

Usage

```
hermite_estimator_bivar(N = 30, standardize = TRUE, exp_weight_lambda = NA)
```

Arguments

N	An integer between 0 and 75. The Hermite series based estimator is truncated at N+1 terms.
standardize	A boolean value. Determines whether the observations are standardized, a transformation which often improves performance.
exp_weight_lambda	A numerical value between 0 and 1. This parameter controls the exponential weighting of the Hermite series based estimator. If this parameter is NA, no exponential weighting is applied.

Details

The hermite_estimator_bivar class allows the sequential or one-pass batch estimation of the full bivariate probability density function and cumulative distribution function along with the Spearman's rank correlation coefficient. It is well suited to streaming data (both stationary and non-stationary) and to efficient estimation in the context of massive or distributed data sets. Indeed,estimators constructed on different subsets of a distributed data set can be consistently merged.

Value

An S3 object of class hermite_estimator_bivar, with methods for density function and distribution function estimation along with Spearman's rank correlation estimation.

Author(s)

Michael Stephanou <michael.stephanou@gmail.com>

Examples

```
hermite_est <- hermite_estimator_bivar(N = 30, standardize = TRUE)
```

---

hermite_estimator_univar

A class to sequentially estimate univariate pdfs, cdfs and quantile functions

---

Description

This method constructs an S3 object with associated methods for univariate nonparametric estimation of pdfs, cdfs and quantiles.

Usage

```
hermite_estimator_univar(N = 30, standardize = TRUE, exp_weight_lambda = NA)
```

Arguments

N	An integer between 0 and 75. The Hermite series based estimator is truncated at N+1 terms.
standardize	A boolean value. Determines whether the observations are standardized, a transformation which often improves performance.
exp_weight_lambda	A numerical value between 0 and 1. This parameter controls the exponential weighting of the Hermite series based estimator. If this parameter is NA, no exponential weighting is applied.

Details

The hermite_estimator_univar class allows the sequential or one-pass batch estimation of the full probability density function, cumulative distribution function and quantile function. It is well suited to streaming data (both stationary and non-stationary) and to efficient estimation in the context of massive or distributed data sets. Indeed, estimators constructed on different subsets of a distributed data set can be consistently merged.

Value

An S3 object of class hermite_estimator_univar, with methods for density function, distribution function and quantile function estimation.

Author(s)

Michael Stephanou <michael.stephanou@gmail.com>

Examples

```
hermite_est <- hermite_estimator_univar(N = 30, standardize = TRUE)
```

---

hermite_function *Outputs orthonormal Hermite functions*

Description

The method calculates the orthonormal Hermite functions, $h_k(x)$ from $k = 0, \ldots, N$ for the vector of values, x.

Usage

```
hermite_function(N, x, normalization)
```

Arguments

N	An integer number.
x	A numeric vector.
normalization	A numeric vector of normalization factors generated by the hermite_normalization function.

Value

A numeric matrix with N+1 rows and length(x) columns.

Author(s)

Michael Stephanou <michael.stephanou@gmail.com>

`hermite_function_N` *Convenience function to output orthonormal Hermite functions The method calculates the orthonormal Hermite functions, h_k(x) from k = 0, ..., N for the vector of values, x.*

Description

Convenience function to output orthonormal Hermite functions

The method calculates the orthonormal Hermite functions, $h_k(x)$ from $k = 0, \ldots, N$ for the vector of values, x.

Usage

```
hermite_function_N(N, x, normalization_hermite = NULL)
```

Arguments

`N`	An integer number.
`x`	A numeric vector.
`normalization_hermite`	A numeric vector. A vector of normalization values necessary in the calculation of the Hermite functions.

Value

A numeric matrix with N+1 rows and length(x) columns.

`hermite_function_sum` *Outputs the sum of orthonormal Hermite functions*

Description

The method calculates the sum of orthonormal Hermite functions, $\sum_i h_k(x_i)$ from $k = 0, \ldots, N$ for the vector of values, x.

Usage

```
hermite_function_sum(N, x, normalization)
```

Arguments

`N`	An integer number.
`x`	A numeric vector.
`normalization`	A numeric vector of normalization factors generated by the hermite_normalization function.

Value

A numeric vector of length N+1.

Author(s)

Michael Stephanou <michael.stephanou@gmail.com>

`hermite_function_sum_N`

Convenience function to output the sum of orthonormal Hermite functions The method calculates the sum of orthonormal Hermite functions, $\sum$_ih_$k(x$_$i)$ from $k = 0, \ldots, N$ for the vector of values, x.

Description

Convenience function to output the sum of orthonormal Hermite functions

The method calculates the sum of orthonormal Hermite functions, $\sum_i h_k(x_i)$ from $k = 0, \ldots, N$ for the vector of values, x.

Usage

```
hermite_function_sum_N(N, x, normalization_hermite = NULL)
```

Arguments

`N`	An integer number.
`x`	A numeric vector.
`normalization_hermite`	A numeric vector of normalization factors generated by the hermite_normalization function.

Value

A numeric vector of length N+1.

hermite_integral_val *Outputs lower integral of the orthonormal Hermite functions*

Description

The method calculates $\int_{-\infty}^{x} h_k(t)dt$ for $k = 0, \ldots, N$ and the vector of values x.

Usage

```
hermite_integral_val(N, x, hermite_function_mat)
```

Arguments

N	An integer number.
x	A numeric vector.
hermite_function_mat	A numeric matrix of Hermite function values generated by the function hermite_function.

Value

A numeric matrix with N+1 rows and length(x) columns.

Author(s)

Michael Stephanou <michael.stephanou@gmail.com>

hermite_integral_val_upper *Outputs upper integral of the orthonormal Hermite functions*

Description

The method calculates $\int_{x}^{\infty} h_k(t)dt$ for $k = 0, \ldots, N$ and the vector of values x.

Usage

```
hermite_integral_val_upper(N, x, hermite_function_mat)
```

Arguments

N	An integer number.
x	A numeric vector.
hermite_function_mat	A numeric matrix of Hermite function values generated by the function hermite_function.

Value

A numeric matrix with N+1 rows and length(x) columns.

Author(s)

Michael Stephanou <michael.stephanou@gmail.com>

`hermite_int_full` *Convenience function to output the integral of the orthonormal Hermite functions on the full domain*

Description

The method calculates $\int_{-\infty}^{\infty} h_k(t)dt$ for $k = 0, \ldots, N$.

Usage

```
hermite_int_full(N)
```

Arguments

`N`	An integer number.

Value

A numeric matrix with N+1 rows and 1 columns.

`hermite_int_full_domain` *Outputs integral of the orthonormal Hermite functions on the full domain*

Description

The method calculates $\int_{-\infty}^{\infty} h_k(t)dt$ for $k = 0, \ldots, N$.

Usage

```
hermite_int_full_domain(N)
```

Arguments

`N`	An integer number.

Value

A numeric matrix with N+1 rows and 1 columns.

Author(s)

Michael Stephanou <michael.stephanou@gmail.com>

`hermite_int_lower` *Convenience function to output a definite integral of the orthonormal Hermite functions*

Description

The method calculates $\int_{-\infty}^{x} h_k(t)dt$ for $k = 0, \ldots, N$ and the vector of values x.

Usage

```
hermite_int_lower(
  N,
  x,
  hermite_function_matrix = NULL,
  normalization_hermite = NULL
)
```

Arguments

`N`	An integer number.
`x`	A numeric vector.
`hermite_function_matrix`	A numeric matrix. A matrix of Hermite function values.
`normalization_hermite`	A numeric vector. A vector of normalization values necessary in the calculation of the Hermite functions.

Value

A numeric matrix with N+1 rows and length(x) columns.

`hermite_int_upper` *Convenience function to output a definite integral of the orthonormal Hermite functions*

Description

The method calculates $\int_{x}^{\infty} h_k(t)dt$ for $k = 0, \ldots, N$ and the vector of values x.

Usage

```
hermite_int_upper(
  N,
  x,
  hermite_function_matrix = NULL,
  normalization_hermite = NULL
)
```

Arguments

N	An integer number.
x	A numeric vector.
hermite_function_matrix	A numeric matrix. A matrix of Hermite function values.
normalization_hermite	A numeric vector. A vector of normalization values necessary in the calculation of the Hermite functions.

Value

A numeric matrix with N+1 rows and length(x) columns.

---

hermite_normalization *Outputs Hermite normalization factors*

Description

The method returns numeric normalization factors that, when multiplied by the physicist Hermite polynomials $H_k(x)$, yield orthonormal Hermite functions $h_k(x)$ for $k = 0, \ldots, N$.

Usage

```
hermite_normalization(N)
```

Arguments

N	An integer number.

Value

A numeric vector of length N+1

Author(s)

Michael Stephanou <michael.stephanou@gmail.com>

`hermite_normalization_N` *Convenience function to output Hermite normalization factors*

Description

The method returns numeric normalization factors that, when multiplied by the physicist Hermite polynomials $H_k(x)$, yield orthonormal Hermite functions $h_k(x)$ for $k = 0, \ldots, N$.

Usage

```
hermite_normalization_N(N)
```

Arguments

`N`	An integer number.

Value

A numeric vector of length N+1

Author(s)

Michael Stephanou <michael.stephanou@gmail.com>

`hermite_polynomial` *Outputs physicist version of Hermite Polynomials*

Description

The method calculates the physicist version of Hermite polynomials, $H_k(x)$ from $k = 0, \ldots, N$ for the vector of values, x.

Usage

```
hermite_polynomial(N, x)
```

Arguments

`N`	An integer number.
`x`	A numeric vector.

Value

A numeric matrix with N+1 rows and length(x) columns.

Author(s)

Michael Stephanou <michael.stephanou@gmail.com>

`hermite_polynomial_N` *Convenience function to output physicist Hermite polynomials The method calculates the physicist version of Hermite polynomials, $H\_k(x)$ from $k = 0, \ldots, N$ for the vector of values, x.*

Description

Convenience function to output physicist Hermite polynomials

The method calculates the physicist version of Hermite polynomials, $H_k(x)$ from $k = 0, \ldots, N$ for the vector of values, x.

Usage

```
hermite_polynomial_N(N, x)
```

Arguments

`N`	An integer number.
`x`	A numeric vector.

Value

A numeric matrix with N+1 rows and length(x) columns.

`kendall` *Estimates the Kendall rank correlation coefficient*

Description

This method calculates the Kendall rank correlation coefficient value. It is only applicable to the bivariate Hermite estimator i.e. est_type = "bivariate".

Usage

```
kendall(this, clipped = FALSE)
```

Arguments

`this`	A hermite_estimator_bivar object.
`clipped`	A boolean value. Indicates whether to clip the Kendall rank correlation estimates to lie between -1 and 1.

Details

The object must be updated with observations prior to the use of this method.

Value

A numeric value.

Examples

```
hermite_est <- hermite_estimator(N = 10, standardize = TRUE,
est_type="bivariate")
hermite_est <- update_batch(hermite_est, matrix(rnorm(30*2), nrow=30,
ncol=2, byrow = TRUE))
kendall_est <- kendall(hermite_est)
```

---

kendall.hermite_estimator_bivar

Estimates the Kendall rank correlation coefficient

Description

This method calculates the Kendall rank correlation coefficient value using the hermite_estimator_bivar object (this).

Usage

```
## S3 method for class 'hermite_estimator_bivar'
kendall(this, clipped = FALSE)
```

Arguments

this	A hermite_estimator_bivar object.
clipped	A boolean value. Indicates whether to clip the Kendall rank correlation estimates to lie between -1 and 1.

Details

The object must be updated with observations prior to the use of this method.

Value

A numeric value.

Examples

```
hermite_est <- hermite_estimator_bivar(N = 10, standardize = TRUE)
hermite_est <- update_batch(hermite_est, matrix(rnorm(30*2), nrow=30,
ncol=2, byrow = TRUE))
kendall_est <- kendall(hermite_est)
```

merge_hermite *Merges a list of Hermite estimators*

Description

Note that the estimators must be of the same type to be merged i.e. all estimators must have a consistent est_type, either "univariate" or "bivariate". In addition, the N and standardize arguments must be the same for all estimators in order to merge them. Finally, note that exponentially weighted estimators cannot be merged. If the Hermite estimators are not standardized, the merged estimator will be exactly equivalent to constructing a single estimator on the data set formed by combining the data sets used to update the respective hermite_estimator inputs. If the input Hermite estimators are standardized however, then the equivalence will be approximate but still accurate in most cases.

Usage

```
merge_hermite(hermite_estimators)
```

Arguments

hermite_estimators	A list of hermite_estimator_univar or hermite_estimator_bivar objects.

Value

An object of class hermite_estimator_univar or hermite_estimator_bivar.

Examples

```
hermite_est_1 <- hermite_estimator(N = 10, standardize = FALSE)
hermite_est_1 <- update_batch(hermite_est_1, rnorm(30))
hermite_est_2 <- hermite_estimator(N = 10, standardize = FALSE)
hermite_est_2 <- update_batch(hermite_est_2, rnorm(30))
hermite_merged <- merge_hermite(list(hermite_est_1, hermite_est_2))
```

merge_hermite_bivar *Merges a list of bivariate Hermite estimators*

Description

This method allows a list of Hermite based estimators of class hermite_estimator_bivar to be consistently merged.

Usage

```
merge_hermite_bivar(hermite_estimators)
```

Arguments

`hermite_estimators`
: A list of hermite_estimator_bivar objects.

Details

Note that the N and standardize arguments must be the same for all estimators in order to merge them. In addition, note that exponentially weighted estimators cannot be merged. If the Hermite estimators are not standardized, the merged estimator will be exactly equivalent to constructing a single estimator on the data set formed by combining the data sets used to update the respective hermite_estimator_bivar inputs. If the input Hermite estimators are standardized however, then the equivalence will be approximate but still accurate in most cases.

Value

An object of class hermite_estimator_bivar.

`merge_hermite_univar` *Merges a list of Hermite estimators*

Description

This method allows a list of Hermite based estimators of class hermite_estimator_univar to be consistently merged.

Usage

```
merge_hermite_univar(hermite_estimators)
```

Arguments

`hermite_estimators`
: A list of hermite_estimator_univar objects.

Details

Note that the N and standardize arguments must be the same for all estimators in order to merge them. In addition, note that exponentially weighted estimators cannot be merged. If the Hermite estimators are not standardized, the merged estimator will be exactly equivalent to constructing a single estimator on the data set formed by combining the data sets used to update the respective hermite_estimator_univar inputs. If the input Hermite estimators are standardized however, then the equivalence will be approximate but still accurate in most cases.

Value

An object of class hermite_estimator_univar.

Examples

```
hermite_est_1 <- hermite_estimator_univar(N = 10, standardize = FALSE)
hermite_est_1 <- update_batch(hermite_est_1, rnorm(30))
hermite_est_2 <- hermite_estimator_univar(N = 10, standardize = FALSE)
hermite_est_2 <- update_batch(hermite_est_2, rnorm(30))
hermite_merged <- merge_hermite(list(hermite_est_1, hermite_est_2))
```

---

merge_moments_and_count_bivar

Internal method to consistently merge the number of observations, means and variances of two bivariate Hermite estimators

---

Description

The algorithm to merge the variances consistently comes from Schubert, Erich, and Michael Gertz. "Numerically stable parallel computation of (co-) variance." Proceedings of the 30th International Conference on Scientific and Statistical Database Management. 2018.

Usage

```
merge_moments_and_count_bivar(hermite_estimator1, hermite_estimator2)
```

Arguments

hermite_estimator1	A hermite_estimator_bivar object.
hermite_estimator2	A hermite_estimator_bivar object.

Value

An object of class hermite_estimator_bivar

---

merge_moments_and_count_univar

Internal method to consistently merge the number of observations, means and variances of two Hermite estimators

---

Description

The algorithm to merge the variances consistently comes from Schubert, Erich, and Michael Gertz. "Numerically stable parallel computation of (co-) variance." Proceedings of the 30th International Conference on Scientific and Statistical Database Management. 2018.

Usage

```
merge_moments_and_count_univar(hermite_estimator1, hermite_estimator2)
```

Arguments

hermite_estimator1	A hermite_estimator_univar object.
hermite_estimator2	A hermite_estimator_univar object.

Value

An object of class hermite_estimator_univar.

---

merge_pair *Merges two Hermite estimators*

Description

Note that the estimators must be of the same type to be merged i.e. both estimators must have a consistent est_type, either "univariate" or "bivariate". In addition, the N and standardize arguments must be the same for both estimators in order to merge them. Finally, note that exponentially weighted estimators cannot be merged. If the Hermite estimators are not standardized, the merged estimator will be exactly equivalent to constructing a single estimator on the data set formed by combining the data sets used to update the respective hermite_estimator inputs. If the input Hermite estimators are standardized however, then the equivalence will be approximate but still accurate in most cases.

Usage

```
merge_pair(this, hermite_estimator_other)
```

Arguments

this	A hermite_estimator_univar or hermite_estimator_bivar object. The first Hermite series based estimator.
hermite_estimator_other	A hermite_estimator_univar or hermite_estimator_bivar object. The second Hermite series based estimator.

Value

An object of class hermite_estimator_univar or hermite_estimator_bivar.

Examples

```
hermite_est_1 <- hermite_estimator(N = 10, standardize = FALSE)
hermite_est_1 <- update_batch(hermite_est_1, rnorm(30))
hermite_est_2 <- hermite_estimator(N = 10, standardize = FALSE)
hermite_est_2 <- update_batch(hermite_est_2, rnorm(30))
hermite_merged <- merge_pair(hermite_est_1, hermite_est_2)
```

---

merge_pair.hermite_estimator_bivar

Merges two bivariate Hermite estimators

Description

This method allows a pair of Hermite based estimators of class hermite_estimator_bivar to be consistently merged.

Usage

```
## S3 method for class 'hermite_estimator_bivar'
merge_pair(this, hermite_estimator_other)
```

Arguments

`this`	A hermite_estimator_bivar object. The first Hermite series based estimator.
`hermite_estimator_other`	A hermite_estimator_bivar object. The second Hermite series based estimator.

Details

Note that the N and standardize arguments must be the same for the two estimators in order to merge them. In addition, note that exponentially weighted estimators cannot be merged. If the Hermite estimators are not standardized, the merged estimator will be exactly equivalent to constructing a single estimator on the data set formed by combining the data sets used to update the respective hermite_estimator_bivar inputs. If the input Hermite estimators are standardized however, then the equivalence will be approximate but still accurate in most cases.

Value

An object of class hermite_estimator_bivar.

merge_pair.hermite_estimator_univar *Merges two Hermite estimators*

Description

This method allows a pair of Hermite based estimators of class hermite_estimator_univar to be consistently merged.

Usage

```
## S3 method for class 'hermite_estimator_univar'
merge_pair(this, hermite_estimator_other)
```

Arguments

this	A hermite_estimator_univar object. The first Hermite series based estimator.
hermite_estimator_other	A hermite_estimator_univar object. The second Hermite series based estimator.

Details

Note that the N and standardize arguments must be the same for the two estimators in order to merge them. In addition, note that exponentially weighted estimators cannot be merged. If the Hermite estimators are not standardized, the merged estimator will be exactly equivalent to constructing a single estimator on the data set formed by combining the data sets used to update the respective hermite_estimator_univar inputs. If the input Hermite estimators are standardized however, then the equivalence will be approximate but still accurate in most cases.

Value

An object of class hermite_estimator_univar.

Examples

```
hermite_est_1 <- hermite_estimator_univar(N = 10, standardize = FALSE)
hermite_est_1 <- update_batch(hermite_est_1, rnorm(30))
hermite_est_2 <- hermite_estimator_univar(N = 10, standardize = FALSE)
hermite_est_2 <- update_batch(hermite_est_2, rnorm(30))
hermite_merged <- merge_pair(hermite_est_1, hermite_est_2)
```

`merge_standardized_helper_bivar` *Internal method to merge a list of standardized bivariate Hermite estimators*

Description

Internal method to merge a list of standardized bivariate Hermite estimators

Usage

```
merge_standardized_helper_bivar(hermite_estimators)
```

Arguments

`hermite_estimators` A list of hermite_estimator_bivar objects.

Value

An object of class hermite_estimator_bivar.

`merge_standardized_helper_univar` *Internal method to merge a list of standardized Hermite estimators*

Description

Internal method to merge a list of standardized Hermite estimators

Usage

```
merge_standardized_helper_univar(hermite_estimators)
```

Arguments

`hermite_estimators` A list of hermite_estimator_univar objects.

Value

An object of class hermite_estimator_univar.

print.hermite_estimator_bivar *Prints bivariate hermite_estimator object.*

Description

Prints bivariate hermite_estimator object.

Usage

```
## S3 method for class 'hermite_estimator_bivar'
print(x, ...)
```

Arguments

x	A hermite_estimator_bivar object.
...	Other arguments passed on to methods used in printing.

Examples

```
hermite_est <- hermite_estimator_bivar(N = 10, standardize = TRUE)
print(hermite_est)
```

print.hermite_estimator_univar *Prints univariate hermite_estimator object.*

Description

Prints univariate hermite_estimator object.

Usage

```
## S3 method for class 'hermite_estimator_univar'
print(x, ...)
```

Arguments

x	A hermite_estimator_univar object.
...	Other arguments passed on to methods used in printing.

Examples

```
hermite_est <- hermite_estimator_univar(N = 10, standardize = TRUE)
print(hermite_est)
```

quant *Estimates the quantiles at a vector of probability values*

Description

This method utilizes the estimator (13) in paper Stephanou, Michael, Varughese, Melvin and Iain Macdonald. "Sequential quantiles via Hermite series density estimation." Electronic Journal of Statistics 11.1 (2017): 570-607 <doi:10.1214/17-EJS1245>, with some modifications to improve the stability of numerical root finding. Note that this method is only applicable to the univariate Hermite estimator i.e. est_type = "univariate".

Usage

```
quant(this, p, algorithm = "interpolate", accelerate_series = TRUE)
```

Arguments

this	A hermite_estimator_univar object.
p	A numeric vector. A vector of probability values.
algorithm	A string. Two possible values 'interpolate' which is faster but may be less accurate or 'bisection' which is slower but potentially more accurate.
accelerate_series	A boolean value. If set to TRUE, the series acceleration methods described in: Boyd, John P., and Dennis W. Moore. "Summability methods for Hermite functions." Dynamics of atmospheres and oceans 10.1 (1986): 51-62. are applied. If set to FALSE, then standard summation is applied.

Value

A numeric vector. The vector of quantile values associated with the probabilities p.

Examples

```
hermite_est <- hermite_estimator(N = 10, standardize = TRUE,
est_type="univariate")
hermite_est <- update_batch(hermite_est, rnorm(30))
quant_est <- quant(hermite_est, c(0.25, 0.5, 0.75))
```

quant.hermite_estimator_univar *Estimates the quantiles at a vector of probability values*

Description

This method utilizes the estimator (13) in paper Stephanou, Michael, Varughese, Melvin and Iain Macdonald. "Sequential quantiles via Hermite series density estimation." Electronic Journal of Statistics 11.1 (2017): 570-607 <doi:10.1214/17-EJS1245>, with some modifications to improve the stability of numerical root finding.

Usage

```
## S3 method for class 'hermite_estimator_univar'
quant(this, p, algorithm = "interpolate", accelerate_series = TRUE)
```

Arguments

this	A hermite_estimator_univar object.
p	A numeric vector. A vector of probability values.
algorithm	A string. Two possible values 'interpolate' which is faster but may be less accurate or 'bisection' which is slower but potentially more accurate.
accelerate_series	A boolean value. If set to TRUE, the series acceleration methods described in: Boyd, John P., and Dennis W. Moore. "Summability methods for Hermite functions." Dynamics of atmospheres and oceans 10.1 (1986): 51-62. are applied. If set to FALSE, then standard summation is applied.

Value

A numeric vector. The vector of quantile values associated with the probabilities p.

Examples

```
hermite_est <- hermite_estimator_univar(N = 10, standardize = TRUE)
hermite_est <- update_batch(hermite_est, rnorm(30))
quant_est <- quant(hermite_est, c(0.25, 0.5, 0.75))
```

spearmans *Estimates the Spearman's rank correlation coefficient*

Description

This method calculates the Spearman's rank correlation coefficient value. It is only applicable to the bivariate Hermite estimator i.e. est_type = "bivariate".

Usage

```
spearmans(this, clipped = FALSE)
```

Arguments

this	A hermite_estimator_bivar object.
clipped	A boolean value. Indicates whether to clip Spearman's rank correlation estimates to lie between -1 and 1.

Details

The object must be updated with observations prior to the use of this method.

Value

A numeric value.

Examples

```
hermite_est <- hermite_estimator(N = 10, standardize = TRUE,
est_type="bivariate")
hermite_est <- update_batch(hermite_est, matrix(rnorm(30*2), nrow=30,
ncol=2, byrow = TRUE))
spearmans_est <- spearmans(hermite_est)
```

spearmans.hermite_estimator_bivar *Estimates the Spearman's rank correlation coefficient*

Description

This method calculates the Spearman's rank correlation coefficient value using the hermite_estimator_bivar object (this).

Usage

```
## S3 method for class 'hermite_estimator_bivar'
spearmans(this, clipped = FALSE)
```

Arguments

this	A hermite_estimator_bivar object.
clipped	A boolean value. Indicates whether to clip Spearman's rank correlation estimates to lie between -1 and 1.

Details

The method utilizes the estimator defined in the paper Stephanou, Michael and Varughese, Melvin. "Sequential Estimation of Nonparametric Correlation using Hermite Series Estimators." arXiv Preprint (2020), https://arxiv.org/abs/2012.06287

The object must be updated with observations prior to the use of this method.

Value

A numeric value.

Examples

```
hermite_est <- hermite_estimator_bivar(N = 10, standardize = TRUE)
hermite_est <- update_batch(hermite_est, matrix(rnorm(30*2), nrow=30,
ncol=2, byrow = TRUE))
spearmans_est <- spearmans(hermite_est)
```

---

standardizeInputs *Standardizes the observation x and updates the online moment inputs*

Description

Standardizes the observation x and updates the online moment inputs

Usage

```
standardizeInputs(x, n_obs, current_mean, current_var)
```

Arguments

x	A numeric value.
n_obs	A numeric value. The number of observations.
current_mean	A numeric value.
current_var	A numeric value.

Value

A numeric vector. The first element is the updated mean. The second element is the updated variance times n_obs. The third element is the updated, standardized value of x.

Author(s)

Michael Stephanou <michael.stephanou@gmail.com>

---

standardizeInputsEW *Standardizes the observation x and updates the online moment inputs*

Description

The online moments are updated via exponential weighting.

Usage

```
standardizeInputsEW(x, n_obs, lambda, current_mean, current_var)
```

Arguments

x	A numeric value.
n_obs	A numeric value. The number of observations.
lambda	A numeric value.
current_mean	A numeric value.
current_var	A numeric value.

Value

A numeric vector. The first element is the updated mean. The second element is the updated variance times n_obs. The third element is the updated, standardized value of x.

Author(s)

Michael Stephanou <michael.stephanou@gmail.com>

---

summary.hermite_estimator_bivar *Summarizes bivariate hermite_estimator object.*

Description

Outputs key parameters of a bivariate hermite_estimator object along with estimates of the mean and standard deviation of the first and second dimensions of the bivariate data that the object has been updated with. Also outputs the Spearman's Rho and Kendall Tau of the bivariate data that the object has been updated with.

Usage

```
## S3 method for class 'hermite_estimator_bivar'
summary(object, digits = max(3, getOption("digits") - 3), ...)
```

Arguments

object	A hermite_estimator_bivar object.
digits	A numeric value. Number of digits to round to.
...	Other arguments passed on to methods used in summary.

Examples

```
hermite_est <- hermite_estimator_bivar(N = 10, standardize = TRUE)
hermite_est <- update_batch(hermite_est, matrix(rnorm(30*2), nrow=30,
ncol=2, byrow = TRUE))
summary(hermite_est)
```

---

summary.hermite_estimator_univar

Summarizes univariate hermite_estimator object.

Description

Outputs key parameters of a univariate hermite_estimator object along with estimates of the mean, standard deviation and deciles of the data that the object has been updated with.

Usage

```
## S3 method for class 'hermite_estimator_univar'
summary(object, digits = max(3, getOption("digits") - 3), ...)
```

Arguments

object	A hermite_estimator_univar object.
digits	A numeric value. Number of digits to round to.
...	Other arguments passed on to methods used in summary.

Examples

```
hermite_est <- hermite_estimator_univar(N = 10, standardize = TRUE)
hermite_est <- update_batch(hermite_est, rnorm(30))
summary(hermite_est)
```

update_batch *Updates the Hermite series based estimator with a batch of data*

Description

This method can be applied in one-pass batch estimation settings. This method cannot be used with an exponentially weighted estimator.

Usage

```
update_batch(this, x)
```

Arguments

this	A hermite_estimator_univar or hermite_estimator_bivar object.
x	A numeric vector or a numeric matrix. Note that for univariate estimators, x is a numeric vector of observations to be incorporated. For bivariate estimators, x is a numeric matrix with n rows for n observations and 2 columns.

Value

An object of class hermite_estimator_univar or hermite_estimator_bivar.

Examples

```
hermite_est <- hermite_estimator(N = 10, standardize = TRUE,
est_type="univariate")
hermite_est <- update_batch(hermite_est, x = c(1, 2))
hermite_est <- hermite_estimator(N = 10, standardize = TRUE,
est_type="bivariate")
hermite_est <- update_batch(hermite_est, x = matrix(c(1,1,2,2,3,3),
nrow=3, ncol=2,byrow=TRUE))
```

update_batch.hermite_estimator_bivar *Updates the Hermite series based estimator with a batch of data*

Description

This method can be applied in one-pass batch estimation settings. This method cannot be used with an exponentially weighted estimator.

Usage

```
## S3 method for class 'hermite_estimator_bivar'
update_batch(this, x)
```

Arguments

this	A hermite_estimator_bivar object.
x	A numeric matrix. A matrix of bivariate observations to be incorporated into the estimator. Each row corresponds to a single bivariate observation.

Value

An object of class hermite_estimator_bivar.

Examples

```
hermite_estimator <- hermite_estimator_bivar(N = 10, standardize = TRUE)
hermite_estimator <- update_batch(hermite_estimator, x = matrix(c(1, 2, 3, 4,
 5, 6),nrow=3, ncol=2, byrow = TRUE))
```

---

update_batch.hermite_estimator_univar

Updates the Hermite series based estimator with a batch of data

---

Description

This method can be applied in one-pass batch estimation settings. This method cannot be used with an exponentially weighted estimator.

Usage

```
## S3 method for class 'hermite_estimator_univar'
update_batch(this, x)
```

Arguments

this	A hermite_estimator_univar object.
x	A numeric vector. A vector of observations to be incorporated into the estimator.

Value

An object of class hermite_estimator_univar.

Examples

```
hermite_est <- hermite_estimator_univar(N = 10, standardize = TRUE)
hermite_est <- update_batch(hermite_est, x = c(1, 2))
```

update_sequential *Updates the Hermite series based estimator sequentially*

Description

This method can be applied in sequential estimation settings.

Usage

```
update_sequential(this, x)
```

Arguments

this	A hermite_estimator_univar or hermite_estimator_bivar object.
x	A numeric value or vector. An observation to be incorporated into the estimator. Note that for univariate estimators, x is a numeric value whereas for bivariate estimators, x is a numeric vector of length 2.

Value

An object of class hermite_estimator_univar or hermite_estimator_bivar.

Examples

```
hermite_est <- hermite_estimator(N = 10, standardize = TRUE,
est_type="univariate")
hermite_est <- update_sequential(hermite_est, x = 2)
hermite_est <- hermite_estimator(N = 10, standardize = TRUE,
est_type="bivariate")
hermite_est <- update_sequential(hermite_est, x = c(1,2))
```

update_sequential.hermite_estimator_bivar *Updates the Hermite series based estimator sequentially*

Description

This method can be applied in sequential estimation settings.

Usage

```
## S3 method for class 'hermite_estimator_bivar'
update_sequential(this, x)
```

Arguments

this	A hermite_estimator_bivar object.
x	A numeric vector of length 2. A bivariate observation to be incorporated into the estimator.

Value

An object of class hermite_estimator_bivar.

Examples

```
hermite_estimator <- hermite_estimator_bivar(N = 10, standardize = TRUE)
hermite_estimator <- update_sequential(hermite_estimator, x = c(1,2))
```

---

update_sequential.hermite_estimator_univar

Updates the Hermite series based estimator sequentially

Description

This method can be applied in sequential estimation settings.

Usage

```
## S3 method for class 'hermite_estimator_univar'
update_sequential(this, x)
```

Arguments

this	A hermite_estimator_univar object.
x	A numeric value. An observation to be incorporated into the estimator.

Value

An object of class hermite_estimator_univar.

Examples

```
hermite_est <- hermite_estimator_univar(N = 10, standardize = TRUE)
hermite_est <- update_sequential(hermite_est, x = 2)
```

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