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Description R and C++ functions to perform exact and approximate optimal transport. All C++ methods can be linked to other R packages via their header files.

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`approxOT` *An R package to perform exact and approximate optimal transport.*

Description

R and C++ functions to perform exact and approximate optimal transport. All C++ methods are linkable to other R packages via their header files.

Author(s)

Eric Dunipace

See Also

Useful links:

- https://github.com/ericdunipace/approxOT
- Report bugs at https://github.com/ericdunipace/approxOT/issues

approxOT_threads *Number of threads used by approxOT*

Description

Get or set the number of OpenMP threads used by approxOT's parallel code (currently the log-scale Sinkhorn algorithm).

Usage

```
approxOT_threads(n = NULL)
```

Arguments

n	Number of threads to use. NULL (the default) only returns the current setting. 0 restores the default of half the available processors.

Details

When the package loads, the number of threads is taken from `getOption("approxOT.threads")` if that is set. Otherwise it is 2 during `R CMD check` (when _R_CHECK_LIMIT_CORES_ is set) and half the available processors in all other cases.

The number of threads never exceeds the number of available processors or the OMP_THREAD_LIMIT environment variable. If approxOT was built without OpenMP support, it is always 1.

Value

If n is NULL, the number of threads in use. Otherwise the previous number of threads, invisibly, so that it can be restored later.

Examples

```
approxOT_threads()
old <- approxOT_threads(1)
approxOT_threads(old)
```

as.matrix.transport.plan *Transform transportation plan to transportation matrix*

Description

Transform transportation plan to transportation matrix

Usage

```
## S3 method for class 'transport.plan'
as.matrix(x, ...)
```

Arguments

x	An object of class transport.plan. See output of transport_plan()
...	Unused arguments

Value

A matrix specifying the minimal joint distribution between samples. Margins will be equal to the marginal distributions of the samples

Examples

```
set.seed(203987)
n <- 5
d <- 2
x <- matrix(rnorm(d*n), nrow=d, ncol=n)
y <- matrix(rnorm(d*n), nrow=d, ncol=n)
#get hilbert sort orders for x in backwards way
trans_plan <- transport_plan(X=x, Y=x, ground_p = 2, p = 2,
                         observation.orientation =  "colwise",
                         method = "hilbert")
trans_matrix <- as.matrix(trans_plan)
print(trans_matrix)
```

---

as.transport.plan *Transform transportation matrix to transportation plan*

Description

Transform transportation matrix to transportation plan

Usage

```
as.transport.plan(transport_matrix, ...)
```

Arguments

transport_matrix	A matrix that is a transportation matrix, i.e. the minimal joint distribution for two samples.
...	Unused arguments

Value

An object of class transport.plan. See output of transport_plan

Examples

```
set.seed(203987)
n <- 5
d <- 2
x <- matrix(stats::rnorm(d*n), nrow=d, ncol=n)
y <- matrix(stats::rnorm(d*n), nrow=d, ncol=n)
#get hilbert sort orders for x in backwards way
trans_plan <- transport_plan(X=x, Y=x, ground_p = 2, p = 2,
                         observation.orientation =  "colwise",
                         method = "hilbert")
trans_matrix <- as.matrix(trans_plan$tplan)
tplan2 <- as.transport.plan(trans_matrix)
all.equal(tplan2, trans_plan$tplan)
```

---

cost_calc *Calculate cost matrix*

Description

Calculate cost matrix

Usage

```
cost_calc(X, Y, ground_p)
```

Arguments

X	matrix of values in first sample. Observations should be by column, not rows.
Y	matrix of Values in second sample. Observations should be by column, not rows.
ground_p	power of the Lp norm to use in cost calculation.

Value

matrix of costs

Examples

```
X <- matrix(rnorm(10*100), 10, 100)
Y <- matrix(rnorm(10*100), 10, 100)
# the Euclidean distance
cost <- cost_calc(X, Y, ground_p = 2)
```

hilbert.projection *Get order along the Hilbert curve*

Description

Get order along the Hilbert curve

Usage

```
hilbert.projection(X, Sigma = NULL)
```

Arguments

X	matrix of values. Observations are unique by rows.
Sigma	Covariance of the data. If provided, uses a Mahalanobis distance.

Value

Index of orders

Examples

```
X <- matrix(rnorm(10*3), 3, 10)
idx <- hilbert.projection(X)
print(idx)
```

is.transport.plan *Check if function is a transport.plan*

Description

Check if function is a transport.plan

Usage

```
is.transport.plan(tplan)
```

Arguments

tplan	An object of class transport.plan. See output of transport_plan

Value

Logical

Examples

```
set.seed(203987)
n <- 5
d <- 2
x <- matrix(rnorm(d*n), nrow=d, ncol=n)
y <- matrix(rnorm(d*n), nrow=d, ncol=n)
#get hilbert sort orders for x in backwards way
trans_plan <- transport_plan(X=x, Y=x, ground_p = 2, p = 2,
                         observation.orientation =  "colwise",
                         method = "hilbert")
print(is.transport.plan(trans_plan))
```

---

transport_options *Function returning supported optimal transportation methods.*

Description

Function returning supported optimal transportation methods.

Usage

```
transport_options()
```

Details

The currently supported methods are

- exact, networkflow: Utilize the networkflow algorithm to solve the exact optimal transport problem
- shortsimplex: Use the shortsimplex algorithm to solve the exact optimal transport problem
- sinkhorn: Use Sinkhorn's algorithm to solve the approximate optimal transport problem
- sinkhorn_log: Use Sinkhorn's algorithm on a log-scale for added stability to solve the approximate optimal transport problem
- greenkhorn: Use the Greenkhorn algorithm to solve the approximate optimal transport problem
- hilbert: Use hilbert sorting to perform approximate optimal transport
- rank: use the average covariate ranks to perform approximate optimal transport
- univariate: Use appropriate optimal transport methods for univariate data
- swapping: Utilize the swapping algorithm to perform approximate optimal transport
- sliced: Use the sliced optimal transport distance

Value

Returns a vector of supported transport methods

`transport_plan` *Optimal transport plans*

Description

Optimal transport plans

Usage

```
transport_plan(
  X,
  Y,
  a = NULL,
  b = NULL,
  p = 2,
  ground_p = 2,
  observation.orientation = c("rowwise", "colwise"),
  method = transport_options(),
  ...
)
```

Arguments

`X`	The covariate data of the first sample.
`Y`	The covariate data of the second sample.
`a`	Optional. Empirical measure of the first sample
`b`	Optional. Empirical measure of the second sample
`p`	The power of the Wasserstein distance
`ground_p`	The power of the Lp norm
`observation.orientation`	Are observations by row ("rowwise") or column ("colwise").
`method`	Which transportation method to use. See transport_options
`...`	Additional arguments for various methods • "niter": The number of iterations to use for the entropically penalized optimal transport distances • "epsilon": The entropy penalty, on the same scale as the cost matrix (the plan is proportional to `exp(-cost/epsilon)`). Should be > 0. • "unbiased": If using Sinkhorn distances, should the distance be de-biased? (TRUE/FALSE) • "nboot": If using sliced Wasserstein distances, specify the number of Monte Carlo samples

Value

a list with slots "tplan" and "cost". "tplan" is the optimal transport plan and "cost" is the optimal transport distance.

Examples

```
set.seed(203987)
n <- 100
d <- 10
x <- matrix(stats::rnorm(d*n), nrow=d, ncol=n)
y <- matrix(stats::rnorm(d*n), nrow=d, ncol=n)
#get hilbert sort orders for x in backwards way
transx <- transport_plan(X=x, Y=x, ground_p = 2, p = 2,
                         observation.orientation =  "colwise",
                         method = "hilbert")
```

---

transport_plan_given_C

Optimal transport plans given a pre-specified cost

Description

Optimal transport plans given a pre-specified cost

Usage

```
transport_plan_given_C(
  mass_x,
  mass_y,
  p = 2,
  cost = NULL,
  method = "exact",
  cost_a = NULL,
  cost_b = NULL,
  ...
)
```

Arguments

mass_x	The empirical measure of the first sample
mass_y	The empirical measure of the second sample.
p	The power of the Wasserstein distance
cost	Specify the cost matrix in advance.
method	The transportation method to use, one of "exact", "networkflow","shortsimplex", "sinkhorn", "greenkhorn"
cost_a	The cost matrix for the first sample with itself. Only used for unbiased Sinkhorn

`cost_b` The cost matrix for the second sample with itself. Only used for unbiased Sinkhorn

`...` Additional arguments for various methods

- "niter": The number of iterations to use for the entropically penalized optimal transport distances
- "epsilon": The entropy penalty, on the same scale as the cost matrix (the plan is proportional to `exp(-cost/epsilon)`). Should be > 0.
- "unbiased": If using Sinkhorn distances, should the distance be de-biased? (TRUE/FALSE)

Value

A transportation plan as an object of class "transport.plan", which is a list with slots "from","to", and "mass".

Examples

```
n <- 32
d <- 5
set.seed(293897)
A <- matrix(stats::rnorm(n*d),nrow=d,ncol=n)
B <- matrix(stats::rnorm(n*d),nrow=d,ncol=n)
transp.meth <- "sinkhorn"
niter <- 1e2
test <- transport_plan_given_C(rep(1/n,n),
rep(1/n,n),  2, cost = cost_calc(A,B,2),
"sinkhorn", niter = niter)
```

---

transport_plan_multimarg

Multimarginal optimal transport plans

Description

Multimarginal optimal transport plans

Usage

```
transport_plan_multimarg(
  ...,
  p = 2,
  ground_p = 2,
  observation.orientation = c("rowwise", "colwise"),
  method = c("hilbert", "univariate", "sliced"),
  nsim = 1000
)
```

Arguments

...	Either data matrices as separate arguments or a list of data matrices. Arguments after the data must be specified by name.
p	The power of the Wasserstein distance to use
ground_p	The power of the Euclidean distance to use
observation.orientation	Are observations by rows or columns
method	One of "hilbert", "univariate", or "sliced"
nsim	Number of simulations to use for the sliced method

Value

transport plan

Examples

```
set.seed(23423)
n <- 100
d <- 10
p <- ground_p <- 2 #euclidean cost, p = 2
x <- matrix(stats::rnorm((n + 11)*d), n + 11 , d)
y <- matrix(stats::rnorm(n*d), n, d)
z <- matrix(stats::rnorm((n +455)*d), n +455, d)

# make data a list
data <- list(x,y,z)

tplan <- transport_plan_multimarg(data, p = p, ground_p = ground_p,
observation.orientation = "rowwise", method = "hilbert")

#' #transpose data works too
datat <- lapply(data, t)

tplan2 <- transport_plan_multimarg(datat, p = p, ground_p = ground_p,
observation.orientation = "colwise",method = "hilbert")
```

---

wasserstein *Calculate the Wasserstein distance*

Description

Calculate the Wasserstein distance

Usage

```
wasserstein(
  X = NULL,
  Y = NULL,
  a = NULL,
  b = NULL,
  cost = NULL,
  tplan = NULL,
  p = 2,
  ground_p = 2,
  method = transport_options(),
  cost_a = NULL,
  cost_b = NULL,
  ...
)
```

Arguments

X	The covariate data of the first sample.
Y	The covariate data of the second sample.
a	Optional. Empirical measure of the first sample
b	Optional. Empirical measure of the second sample
cost	Specify the cost matrix in advance.
tplan	Give a transportation plan with slots "from", "to", and "mass", like that returned by the `transport_plan()` function.
p	The power of the Wasserstein distance
ground_p	The power of the Lp norm
method	Which transportation method to use. See `transport_options()`
cost_a	The cost matrix for the first sample with itself. Only used for unbiased Sinkhorn
cost_b	The cost matrix for the second sample with itself. Only used for unbiased Sinkhorn
...	Additional arguments for various methods: • "niter": The number of iterations to use for the entropically penalized optimal transport distances • "epsilon": The entropy penalty, on the same scale as the cost matrix (the plan is proportional to `exp(-cost/epsilon)`). Should be > 0. • "unbiased": If using Sinkhorn distances, should the distance be de-biased? (TRUE/FALSE) • "nboot": If using sliced Wasserstein distances, specify the number of Monte Carlo samples

Value

The p-Wasserstein distance, a numeric value

Examples

```
set.seed(11289374)
n <- 100
z <- stats::rnorm(n)
w <- stats::rnorm(n)
uni <- approxOT::wasserstein(X = z, Y = w,
p = 2, ground_p = 2,
observation.orientation = "colwise",
method = "univariate")
```

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