Package ‘PerMallows’

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Type Package

Title Permutations and Mallows Distributions

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Description Includes functions to work with the Mallows and Generalized Mallows Models. The considered distances are Kendall's-tau, Cayley, Hamming and Ulam and it includes functions for making inference, sampling and learning such distributions, some of which are novel in the literature. As a by-product, PerMallows also includes operations for permutations, paying special attention to those related with the Kendall's-tau, Cayley, Ulam and Hamming distances. It is also possible to generate random permutations at a given distance, or with a given number of inversions, or cycles, or fixed points or even with a given length on LIS (longest increasing subsequence).

License GPL (>= 2)

Depends Rcpp (>= 0.10.3)

Imports utils

LinkingTo Rcpp

RoxygenNote 5.0.1

R topics documented:

`compose` *Compose permutations*

Description

This function composes two given permtuations. One of the arguments can be a collection of permutations, but not both at the same time. In this case, every permutation in the collection is composed with the other argument

Usage

```
compose(perm1, perm2)
```

Arguments

`perm1`	a permtuation or a collection of permutations
`perm2`	a permtuation or a collection of permutations

Value

The composition of the permutations

Examples

```
compose(c(3,1,2,4), c(4,1,3,2))
```

count.perms — *Count permutations at a distance*

Description

Given a distance (kendall, cayley, hamming or ulam), the number of items in the permutations perm.length and distance value d, how many permutations are there at distance d from any permutation? It can be used to count the number of derangements and the permutations with k cycles (Stirling numbers of the first kind)

Usage

```
count.perms(perm.length, dist.value, dist.name = "kendall", disk = FALSE)
```

Arguments

`perm.length`	number of items in the permutations
`dist.value`	the distance
`dist.name`	optional. One of: kendall (default), cayley, hamming, ulam
`disk`	optional can only be true if counting the permutations at each Ulam distance. Insted of generating the whole set of SYT and count of permutations per distance, it loads the info from a file in the disk

Value

The number of permutations at the given distance

Examples

```
count.perms(4,2,"kendall")
count.perms(4,2,"ulam")
count.perms(4,2,"hamming")
count.perms(4,2,"cayley")
# The number of derangements of length 6 is computed as follows
len <- 6
count.perms(perm.length = len, dist.value = len, dist.name = "h")
# The number of permutations with one cycle is computed as follows
num.cycles <- 1
count.perms(perm.length = len, dist.value = len - num.cycles, dist.name = "c")
```

cycle2str — *Friendly display the cycles*

Description

Given a list with the cycles of a permutation, displays them in the standard cycle notation

Usage

```
cycle2str(cy)
```

Arguments

`cy`	a list with the set of cycles

Examples

```
cycle2str(perm2cycles(c(1,5,2,3,4)))
```

`cycles2perm` *Get the permutation given the cycles*

Description

Get the permutation as a vector given the set of cycles in which it factorizes

Usage

```
cycles2perm(cycles)
```

Arguments

`cycles`	a list with the set of disjoint cycles

Value

The permutation in vector notation

Examples

```
cycles2perm(perm2cycles(c(1,5,2,3,4)))
```

`data.apa` *Sample of permutations APA*

Description

A rda file containing a sample of permutations of the American Psychology Association

Format

Each row is a permtuation

`data.order` *Sample of permutations*

Description

A rda file containing a sample of permutations

Format

Each row is a permtuation

`decomp2perm` *Get a permutation consistent with a decomposition vector*

Description

Given a distance decomposition vector and a distance name, generate uniformly at random a permutation consistent with the decomposition vector.

Usage

```
decomp2perm(vec, dist.name = "kendall")
```

Arguments

`vec`	the permutation
`dist.name`	optional the name of the distance. One of: kendall (default), cayley, hamming

Value

The distance decomposition vector of the given permutation and distance

Examples

```
decomp2perm(c(1,0,1,0,0), "kendall")
decomp2perm(c(1,0,1,0,0), "cayley")
decomp2perm(c(1,0,1,0,0), "hamming")
```

`dgmm` *Calculate the probability of a permutation in a GMM*

Description

Calculate the probability of a permutation sigma in a GMM of center sigma0, dispersion parameter theta and under the specified distance

Usage

```
dgmm(perm, sigma0 = identity.permutation(length(perm)), theta,
  dist.name = "kendall")
```

Arguments

`perm`	permutation whose probability wants to be known
`sigma0`	central permuation of the GMM, by default the identity
`theta`	vector dispersion parameter of the GMM
`dist.name`	optional name of the distance used in the GMM. One of: kendall (default), cayley, hamming

Value

The probability of sigma in the given GMM

Examples

```
data <- matrix(c(1,2,3,4, 1,4,3,2, 1,2,4,3), nrow = 3, ncol = 4, byrow = TRUE)
sig <- c(1,2,3,4)
th <- c(0.1, 0.2, 0.3,1)
log.prob <- apply(data,MARGIN=1,FUN=function(x){log(dgmm(x,sig, th, "hamming"))})
sum(log.prob)
dgmm (c(1,2,3,4), theta=c(1,1,1))
dgmm (c(1,2,3,4), theta=c(1,1,1), dist.name="cayley")
```

`distance` *Compute the distance between permutations*

Description

Compute the distance between two given permutations. If only one permutation is given the other one is assumed to be the identity (1,2,3,....,n) The distance can be kendall, cayley, hamming and ulam

Usage

```
distance(perm1, perm2 = identity.permutation(length(perm1)),
  dist.name = "kendall")
```

Arguments

`perm1`	a permutation
`perm2`	optional a permutation
`dist.name`	optional. One of: kendall (default), cayley, hamming, ulam

Value

The distance between the permutations

Examples

```
distance(c(1,2,3,5,4))
distance(c(1,2,3,5,4), c(1,2,3,5,4))
distance(c(1,2,3,5,4), c(1,4,2,3,5), "cayley")
```

dmm *Calculate the probability of a permutation in a MM*

Description

Calculate the probability of a permutation sigma in a MM of center sigma0, dispersion parameter theta and under the specified distance

Usage

```
dmm(perm, sigma0 = identity.permutation(length(perm)), theta,
  dist.name = "kendall")
```

Arguments

perm	permutation whose probability is asked for
sigma0	optional central permuation of the MM, by default the identity
theta	dispersion parameter of the MM
dist.name	optional name of the distance used in the MM. One of: kendall (default), cayley, hamming, ulam

Value

The probability of sigma in the given MM

Examples

```
data <- matrix(c(1,2,3, 4,1,4,3,2,1,2,4,3), nrow = 3, ncol = 4, byrow = TRUE)
sig<-c(1,2,3,4)
log.prob <- apply(data,MARGIN=1,FUN=function(x){log(dmm(x,sig, 1,"cayley"))})
sum(log.prob)
dmm(c(1,3,2,4), theta=0.1)
dmm(c(1,3,2,4), theta=0.1, dist.name="cayley")
dmm(c(1,3,2,4), theta=0.1, dist.name="hamming")
dmm(c(1,3,2,4), theta=0.1, dist.name="ulam")
```

expectation.gmm *Compute the expected distance, GMM under the Hamming distance*

Description

Compute the expected distance in the GMM under the Hamming distance

Usage

```
expectation.gmm(theta, dist.name = "kendall")
```

Arguments

theta	n dimensional real vector with the dispersion parameters
dist.name	optional name of the distance used in the GMM. One of: kendall (default), cayley, hamming

Value

The expected distance decomposition vector under the GMM

References

"Ekhine Irurozki, Borja Calvo, Jose A. Lozano (2016). PerMallows: An R Package for Mallows and Generalized Mallows Models. Journal of Statistical Software, 71(12), 1-30. doi:10.18637/jss.v071.i12"

Examples

```
expectation.gmm(c(0.38, 0.44, 0.1, 0.2, 1, 0.1))
expectation.gmm(c(2, 2, 2, 2),"cayley")
expectation.gmm(c(0.3, 0.1, 0.5, 0.1),"hamming")
```

---

expectation.mm *Compute the expected distance, MM under the Hamming distance*

Description

Compute the expected distance in the MM under the Hamming distance

Usage

```
expectation.mm(theta, perm.length, dist.name = "kendall")
```

Arguments

theta	real dispersion parameter
perm.length	length of the permutation in the considered model
dist.name	optional name of the distance used in the MM. One of: kendall (default), cayley, hamming, ulam

Value

The expected distance under the MM

References

"Ekhine Irurozki, Borja Calvo, Jose A. Lozano (2016). PerMallows: An R Package for Mallows and Generalized Mallows Models. Journal of Statistical Software, 71(12), 1-30. doi:10.18637/jss.v071.i12"

Examples

```
expectation.mm( 1, 7, "kendall" )
expectation.mm( 2, 5, "cayley" )
expectation.mm( 2, 4, "hamming" )
expectation.mm( 1, 6, "ulam" )
```

freq.matrix *Compute the frequency matrix*

Description

Compute the first order marginal probability. In other words, given at least one permutation, calculate the proportion of them that have each item in each position

Usage

```
freq.matrix(perm)
```

Arguments

`perm`	a permutation or a collection of them

Value

A matrix with n rows and n columns with the proportion of the permutations in the input that have each item in each position

Examples

```
freq.matrix(c(1,3,2,4,5))
```

generate.aux.files *Generates the files for Ulam*

Description

Generates files for Ulam which are aimed to accelelrate the processes of counting the number of permutations at ech distance, sampling and learning IFF these operations are going to be computted more than once

Usage

```
generate.aux.files(perm.length)
```

Arguments

`perm.length`	number of items in the permutations

Value

Nothing. Only writes in the current folder the axiliary files

Examples

```
generate.aux.files(4)
```

`identity.permutation` *Generate identity the permutation*

Description

This function generates the identity permutation of a given number of items

Usage

```
identity.permutation(perm.length)
```

Arguments

`perm.length`	number of items in the permutation

Value

The identity permutation of the specified number of items

Examples

```
identity.permutation(3)
identity.permutation(7)
```

`insert` *Insert operator*

Description

Given a permutation and two positions i, j, move item in position i to position j

Usage

```
insert(perm, i, j)
```

Arguments

`perm`	a permutation
`i`	position of the permutation
`j`	position of the permutation

Value

The permutation in the input in which th eoperation has been applied

Examples

```
insert(c(1,2,3,4,5),5,2)
insert(c(1,2,3,4,5),2,5)
```

inverse.perm *Generate inverse permutation*

Description

This function generates the inverse of a given permutation. If the input is a matrix of permutations, invert all the permutations in the input.

Usage

```
inverse.perm(perm)
```

Arguments

perm	a permutation or matrix of permutations

Value

The inverse permutation. If the input is a matrix,the matrix with the inverses

Examples

```
inverse.perm(c(1,2,3,4))
inverse.perm(c(2,3,4,1))
data <- matrix(c(1,2,3, 4,1,4,3,2,1,2,4,3), nrow = 3, ncol = 4, byrow = TRUE)
inverse.perm(data)
```

inversion *Inversion operator*

Description

Given a permutation and a position, swap positions i and i+1

Usage

```
inversion(perm, i)
```

Arguments

perm	a permutation
i	position of the permutation

Value

The permutation in the input with an inversion at the specified position

Examples

```
inversion(c(1,2,3,4,5),2)
```

is.permutation *Check if its argument is a permutation*

Description

This function tests if the given argument is a permutation of the first n natural integers (excluding 0)

Usage

```
is.permutation(perm)
```

Arguments

perm	a vector (or a bidimensional matrix)

Value

TRUE iff perm is a valid permutation (or a matrix of valid permutations)

Examples

```
is.permutation(c(3,1,2,4))
is.permutation(c(6,1,2,3))
is.permutation(matrix(c(1,2,3, 4,1,4,3,2,1,2,4,3), nrow = 3, ncol = 4, byrow = TRUE))
```

lgmm *Learn a Generalized Mallows Model*

Description

Learn the parameter of the distribution of a sample of n permutations comming from a Generalized Mallows Model (GMM).

Usage

```
lgmm(data, sigma_0_ini = identity.permutation(dim(data)[2]),
  dist.name = "kendall", estimation = "approx")
```

Arguments

data	the matrix with the permutations to estimate
sigma_0_ini	optional the initial guess for the consensus permutation
dist.name	optional name of the distance used by the GMM. One of: kendall (default), cayley, hamming
estimation	optional select the approximated or the exact. One of: approx, exact

Value

A list with the parameters of the estimated distribution: the mode and the dispersion parameter vector

References

"Ekhine Irurozki, Borja Calvo, Jose A. Lozano (2016). PerMallows: An R Package for Mallows and Generalized Mallows Models. Journal of Statistical Software, 71(12), 1-30. doi:10.18637/jss.v071.i12"

Examples

```
data <- matrix(c(1,2,3,4, 1,4,3,2, 1,2,4,3), nrow = 3, ncol = 4, byrow = TRUE)
lgmm(data, dist.name="kendall", estimation="approx")
lgmm(data, dist.name="cayley", estimation="approx")
lgmm(data, dist.name="cayley", estimation="exact")
lgmm(data, dist.name="hamming", estimation="approx")
```

`lgmm.theta` *MLE for theta - Generalized Mallows Model*

Description

Compute the MLE for the dispersion parameter (theta) given a sample of n permutations and a central permutation

Usage

```
lgmm.theta(data, sigma_0 = identity.permutation(dim(data)[2]),
  dist.name = "kendall")
```

Arguments

`data`	the matrix with the permutations to estimate
`sigma_0`	optional the initial guess for the consensus permutation. If not given it is assumed to be the identity permutation
`dist.name`	optional name of the distance used by the GMM. One of: kendall (default), cayley, hamming

Value

The MLE for the dispersion parameter

Examples

```
data <- matrix(c(1,2,3,4, 1,4,3,2, 1,2,4,3), nrow = 3, ncol = 4, byrow = TRUE)
lgmm.theta(data, dist.name="kendall")
lgmm.theta(data, dist.name="cayley")
lgmm.theta(data, dist.name="cayley", sigma_0=c(1,4,3,2))
lgmm.theta(data, dist.name="hamming")
```

lmm	*Learn a Mallows Model*

Description

Learn the parameter of the distribution of a sample of n permutations comming from a Mallows Model (MM).

Usage

```
lmm(data, sigma_0_ini = identity.permutation(dim(data)[2]),
  dist.name = "kendall", estimation = "approx", disk = FALSE)
```

Arguments

`data`	the matrix with the permutations to estimate
`sigma_0_ini`	optional the initial guess for the consensus permutation
`dist.name`	optional the name of the distance used by the model. One of: kendall (default), cayley, hamming, ulam
`estimation`	optional select the approximated or the exact. One of: approx, exact
`disk`	optional can only be true if estimating a MM under the Ulam distance. Insted of generating the whole set of SYT and count of permutations per distance, it loads the info from a file in the disk

Value

A list with the parameters of the estimated distribution: the mode and the dispersion parameter

References

"Ekhine Irurozki, Borja Calvo, Jose A. Lozano (2016). PerMallows: An R Package for Mallows and Generalized Mallows Models. Journal of Statistical Software, 71(12), 1-30. doi:10.18637/jss.v071.i12"

Examples

```
data <- matrix(c(1,2,3,4, 1,4,3,2, 1,2,4,3), nrow = 3, ncol = 4, byrow = TRUE)
lmm(data, dist.name="kendall", estimation="approx")
lmm(data, dist.name="cayley", estimation="approx")
lmm(data, dist.name="cayley", estimation="exact")
lmm(data, dist.name="hamming", estimation="exact")
lmm(data, dist.name="ulam", estimation="approx")
```

lmm.theta — *MLE for theta - Mallows Model*

Description

Compute the MLE for the dispersion parameter (theta) given a sample of n permutations and a central permutation

Usage

```
lmm.theta(data, sigma_0 = identity.permutation(dim(data)[2]),
  dist.name = "kendall", disk = FALSE)
```

Arguments

data	the matrix with the permutations to estimate
sigma_0	optional the consensus permutation. If not given it is assumed to be the identity permutation
dist.name	optional the name of the distance used by the model. One of: kendall (default), cayley, hamming, ulam
disk	optional can only be true if estimating a MM under the Ulam distance. Insted of generating the whole set of SYT and count of permutations per distance, it loads the info from a file in the disk

Value

The MLE for the dispersion parameter

Examples

```
data <- matrix(c(1,2,3,4, 1,4,3,2, 1,2,4,3), nrow = 3, ncol = 4, byrow = TRUE)
lmm.theta(data, dist.name="kendall")
lmm.theta(data, dist.name="cayley")
lmm.theta(data, dist.name="cayley", sigma_0=c(1,4,3,2))
lmm.theta(data, dist.name="hamming")
lmm.theta(data, dist.name="ulam")
```

marginal — *Compute the marginal probability, GMM under the Hamming distance*

Description

Compute the marginal probability, GMM under the Hamming distance, of a distance decomposition vector for which some positions are known and some are not

Usage

```
marginal(h, theta)
```

Arguments

`h`	n dimensional distance decomposition vector where h_j = 0 means that j is a fixed point, h_j = 1 means that j is an unfixed point and otherwise j is not known
`theta`	n dimensional distance decomposition vector with the dispersion parameters

Value

The marginal probability

References

"Ekhine Irurozki, Borja Calvo, Jose A. Lozano (2016). PerMallows: An R Package for Mallows and Generalized Mallows Models. Journal of Statistical Software, 71(12), 1-30. doi:10.18637/jss.v071.i12"

Examples

```
marginal(c(1,0,1,NA,NA), c(0.1, 0.3, 0.7, 0.1, 1))
marginal(c(NA,0,1,NA,NA,0), c(0.1, 0.3, 0.7, 0.1, 0.7, 1))
```

`maxi.dist` *Get the maximum value of the distance ebtween permutations*

Description

Compute the maximum posible value for the distance between two given permutations. The distance can be kendall, cayley, hamming and ulam

Usage

```
maxi.dist(perm.length, dist.name = "kendall")
```

Arguments

`perm.length`	number of items in the permutations
`dist.name`	optional. One of: kendall (default), cayley, hamming, ulam

Value

The maximum value for the distance between the permutations

Examples

```
maxi.dist(4,"cayley")
maxi.dist(10,"ulam")
maxi.dist(4)
```

`order.ratings` *Convert rating to permutation*

Description

This function is given a collection of ratings and converts each row to a permutation

Usage

```
order.ratings(ratings)
```

Arguments

`ratings`	a matrix in which each row is a vector of ratings of several items

Value

A matrix in which each row is the corresponding permutation of the items

Examples

```
order.ratings(c(0.1, 4, 0.5, -4))
```

`perm.sample.med` *Sample of permutations*

Description

A rda file containing a sample of permutations

Format

Each row is a permtuation

`perm.sample.small` *Sample of permutations*

Description

A rda file containing a sample of permutations

Format

Each row is a permtuation

perm2cycles — *Decompose a permutation in a set of cycles*

Description

Factor a given a permutation in the set of independent cycles

Usage

```
perm2cycles(perm)
```

Arguments

`perm`	a permutation

Value

The permutation in the input in which the operation has been applied

Examples

```
perm2cycles(c(1,5,2,3,4))
```

perm2decomp — *Get the decomposition vector*

Description

Given a permutation and a distance name generate the decomposition vector

Usage

```
perm2decomp(perm, dist.name = "kendall")
```

Arguments

`perm`	the permutation
`dist.name`	optional the name of the distance. One of: kendall (default), cayley, hamming

Value

The distance decomposition vector of the given permutation and distance. For the Kendall distance is the inversion vector

Examples

```
perm2decomp(c(1,2,4,3,5), "kendall")
perm2decomp(c(1,2,4,3,5), "cayley")
perm2decomp(c(1,2,4,3,5), "hamming")
```

permutations.of *Generate every permutation of perm.length item*

Description

This functions returns a matrix in thich each of rows is a different permutation of the specified number of items

Usage

```
permutations.of(perm.length, alert = TRUE)
```

Arguments

perm.length	number of items in the permutation
alert	optional ask for confirmation when the number of permtuations to show is very large

Value

A collection of every permutation of the specified number of items

Examples

```
permutations.of(3)
permutations.of(10)
```

rdist *Generate a collection of permutations at a given distance*

Description

Given a number of permutations, the number of items in the permutations, a distance value and a distance name, generate a sample of permutations with the specified length at the given distance. Can be used to generate derangements and permutations of a given number of cycles

Usage

```
rdist(n, perm.length, dist.value, dist.name = "kendall")
```

Arguments

n	number of permutations in the sample
perm.length	number of items in the permutations
dist.value	distance value
dist.name	distance name. One of: kendall (default), cayley, hamming, ulam

Value

A sample of permutations at the given distance

Examples

```
rdist(1, 4, 2 )
rdist(1, 4, 2, "ulam")
len <-  3
rdist(n = 1, perm.length = len, dist.value = len, "h") #derangement
cycles <- 2
rdist(n = 1, perm.length = len, dist.value = len - cycles, "c") #permutation with 2 cycles
```

---

read.perms *Read a text file with a collection of permtuations*

Description

This function reads the text file in the specified path and checks if each row is a proper permutation

Usage

```
read.perms(path)
```

Arguments

path	string with a path

Value

A collection of permutations in matrix form

Examples

```
path = system.file("test.txt", package="PerMallows")
sample = read.perms(path)
```

---

rgmm *Sample a Generalized Mallows Model*

Description

Generate a sample of n permutations from a Generalized Mallows Model (GMM).

Usage

```
rgmm(n, sigma0, theta, dist.name = "kendall",
  sampling.method = "multistage")
```

Arguments

`n`	the number of permutations to be generated
`sigma0`	central permuation of the GMM
`theta`	dispersion parameter vector of the GMM
`dist.name`	optional used name of the distance used in the GMM. One of: kendall (default), cayley, hamming
`sampling.method`	optional name of the sampling algorithm. One of: multistage, gibbs (default)

Value

A matrix contaning a sample of permutations from the specified ditribution

References

"Ekhine Irurozki, Borja Calvo, Jose A. Lozano (2016). PerMallows: An R Package for Mallows and Generalized Mallows Models. Journal of Statistical Software, 71(12), 1-30. doi:10.18637/jss.v071.i12"

Examples

```
rgmm(2,c(1,2,3,4,5),c(1,1,1,1),"kendall", "multistage")
rgmm(2,c(1,2,3,4,5),c(1,1,1,1),"cayley", "multistage")
rgmm(2,c(1,2,3,4,5),c(1,1,1,1,1),"hamming", "multistage")
rgmm(2,c(1,2,3,4,5),c(1,1,1,1),"cayley", "gibbs")
rgmm(2,c(1,2,3,4,5),c(1,1,1,1,1),"hamming", "gibbs")
```

`rmm` *Sample a Mallows Model*

Description

Generate a sample of n permutations from a Mallows Model (MM).

Usage

```
rmm(n, sigma0, theta, dist.name = "kendall", sampling.method = NULL,
  disk = FALSE, alert = TRUE)
```

Arguments

`n`	the number of permutations to be generated
`sigma0`	central permuation of the MM
`theta`	dispersion parameter of the MM
`dist.name`	optional name of the distance used in the MM. One of: kendall (default), cayley, hamming, ulam
`sampling.method`	optional name of the sampling algorithm. One of: distances, multistage, gibbs (default)
`disk`	optional can only be true if using the Distances sampling algorithm for generating under the Ulam distance. Insted of generating the whole set of SYT and count of permutations per distance, it loads the info from a file in the disk
`alert`	check consistency of the parameters. TRUE by default

Value

A matrix contaning a sample of permutations from the specified ditribution

References

"Ekhine Irurozki, Borja Calvo, Jose A. Lozano (2016). PerMallows: An R Package for Mallows and Generalized Mallows Models. Journal of Statistical Software, 71(12), 1-30. doi:10.18637/jss.v071.i12"

Examples

```
rmm(2,c(1,2,3,4,5),1,"kendall", "distances")
rmm(2,c(1,2,3,4,5),1,"cayley", "distances")
rmm(2,c(1,2,3,4,5),1,"hamming", "distances")
rmm(2,c(1,2,3,4,5),1,"ulam", "distances")
rmm(2,c(1,2,3,4,5),1,"kendall", "multistage")
rmm(2,c(1,2,3,4,5),1,"cayley", "multistage")
```

---

runif.permutation *Random permutation*

Description

Generate a collection of n permutations uniformly at random

Usage

```
runif.permutation(n = 1, perm.length)
```

Arguments

n	optional number of permutations to generate
perm.length	length of the permutations generated

Value

A single permutation or a matrix with n rows, each being a permutation. Every permutation is drawn uniformly at random and has length perm.length

Examples

```
runif.permutation(1,5)
```

`swap` *Swap two items of a permutation*

Description

Given a permutation and two position, swap both positions

Usage

```
swap(perm, i, j)
```

Arguments

`perm`	a permutation
`i`	position of the permutation
`j`	position of the permutation

Value

The permutation in the input in which the two speicfied items have been swapped

Examples

```
swap(c(1,2,3,4,5),2,5)
```

Index