# Package: rmi (via r-universe)

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**Title** Mutual Information Estimators

**Version** 0.1.1

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**Description** Provides mutual information estimators based on k-nearest neighbor estimators by A. Kraskov, et al. (2004) <doi:10.1103/PhysRevE.69.066138>, S. Gao, et al. (2015) <http://proceedings.mlr.press/v38/gao15.pdf> and local density estimators by W. Gao, et al. (2017) <doi:10.1109/ISIT.2017.8006749>.

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**Repository** https://cranhaven.r-universe.dev

**RemoteUrl** https://github.com/cranhaven/cranhaven.r-universe.dev

**RemoteRef** package/rmi

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`estimate_mse` *Estimate MSE of LNC Estimator*

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## Description

Computes the MSE of the Local Non-Uniformity Correct (LNC) KSG estimator for a given value of the tuning parameter `alpha`, dimension, neighborhood order, and sample size.

## Usage

```
estimate_mse(k = 5, alpha = 0, d = 2, rho = 0, N = 1000,
  M = 100, cluster = NULL)
```

## Arguments

| | |
|---|---|
| `k` | Neighborhood order. |
| `alpha` | Non-uniformity threshold (see details). |
| `d` | Dimension. |
| `rho` | Reference correlation (see details). |
| `N` | Sample size. |
| `M` | Number of replications. |
| `cluster` | A `parallel` cluster object. |

## Details

The parameter `alpha` controls the threshold for the application of the non-uniformity correction to a particular point's neighborhood. Roughly, `alpha` is the ratio of the PCA aligned neighborhood volume to the rectangular aligned neighborhood volume below which indicates non-uniformity and the correction is applied.

If `alpha < 0` then a log scale is assumed; otherwise [0,1] scale is used. `alpha > 1` are unacceptable values. A value of `alpha = 0` forces no correction and LNC reverts to the KSG estimator.

The reference distribution that is assumed is a mean-zero multivariate normal distribution with a compound-symmetric covariance. The covariance matrix has a single correlation parameter supplied by `rho`.

### Examples

```
estimate_mse(N = 100,M = 2)
```

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knn_mi *kNN Mutual Information Estimators*

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### Description

Computes mutual information based on the distribution of nearest neighborhood distances. Method available are KSG1 and KSG2 as described by Kraskov, et. al (2004) and the Local Non-Uniformity Corrected (LNC) KSG as described by Gao, et. al (2015). The LNC method is based on KSG2 but with PCA volume corrections to adjust for observed non-uniformity of the local neighborhood of each point in the sample.

### Usage

```
knn_mi(data, splits, options)
```

### Arguments

| | |
|---|---|
| `data` | Matrix of sample observations, each row is an observation. |
| `splits` | A vector that describes which sets of columns in `data` to compute the mutual information between. For example, to compute mutual information between two variables use `splits = c(1,1)`. To compute *redundancy* among multiple random variables use `splits = rep(1,ncol(data))`. To compute the mutual information between two random vector list the dimensions of each vector. |
| `options` | A list that specifies the estimator and its necessary parameters (see details). |

### Details

Current available methods are LNC, KSG1 and KSG2.

For KSG1 use: `options = list(method = "KSG1", k = 5)`

For KSG2 use: `options = list(method = "KSG2", k = 5)`

For LNC use: `options = list(method = "LNC", k = 10, alpha = 0.65)`, order needed `k > ncol(data)`.

### Author

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### References

Gao, S., Ver Steeg G., & Galstyan A. (2015). Efficient estimation of mutual information for strongly dependent variables. Artificial Intelligence and Statistics: 277-286.

Kraskov, A., Stogbauer, H., & Grassberger, P. (2004). Estimating mutual information. Physical review E 69(6): 066138.

## Examples

```
set.seed(123)
x <- rnorm(1000)
y <- x + rnorm(1000)
knn_mi(cbind(x,y),c(1,1),options = list(method = "KSG2", k = 6))

set.seed(123)
x <- rnorm(1000)
y <- 100*x + rnorm(1000)
knn_mi(cbind(x,y),c(1,1),options = list(method = "LNC", alpha = 0.65, k = 10))
#approximate analytic value of mutual information
-0.5*log(1-cor(x,y)^2)

z <- rnorm(1000)
#redundancy I(x;y;z) is approximately the same as I(x;y)
knn_mi(cbind(x,y,z),c(1,1,1),options = list(method = "LNC", alpha = c(0.5,0,0,0), k = 10))
#mutual information I((x,y);z) is approximately 0
knn_mi(cbind(x,y,z),c(2,1),options = list(method = "LNC", alpha = c(0.5,0.65,0), k = 10))
```

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`lnn_entropy` *Local Nearest Neighbor (LNN) Entropy Estimator*

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## Description

Local Nearest Neighbor entropy estimator using Gaussian kernel and kNN selected bandwidth. Entropy is estimated by taking a Monte Carlo estimate using local kernel density estimate of the negative-log density.

## Usage

```
lnn_entropy(data, k = 5, tr = 30, bw = NULL)
```

## Arguments

| | |
|---|---|
| `data` | Matrix of sample observations, each row is an observation. |
| `k` | Order of the local kNN bandwidth selection. |
| `tr` | Order of truncation (number of neighbors to include in entropy). |
| `bw` | Bandwidth (optional) manually fix bandwidth instead of using local kNN bandwidth selection. |

## References

Loader, C. (1999). Local regression and likelihood. Springer Science & Business Media.

Gao, W., Oh, S., & Viswanath, P. (2017). Density functional estimators with k-nearest neighbor bandwidths. IEEE International Symposium on Information Theory - Proceedings, 1, 1351–1355.

## Examples

```
set.seed(123)
x <- rnorm(1000)
print(lnn_entropy(x))
#analytic entropy
print(0.5*log(2*pi*exp(1)))
```

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lnn_mi *Local Nearest Neighbor (LNN) MI Estimator*

---

## Description

Local Nearest Neighbor (LNN) mutual information estimator by Gao et al. 2017. This estimator uses the LNN entropy (`lnn_entropy`) estimator into the mutual information identity.

## Usage

```
lnn_mi(data, splits, k = 5, tr = 30)
```

## Arguments

| | |
|---|---|
| `data` | Matrix of sample observations, each row is an observation. |
| `splits` | A vector that describes which sets of columns in `data` to compute the mutual information between. For example, to compute mutual information between two variables use `splits = c(1,1)`. To compute *redundancy* among multiple random variables use `splits = rep(1,ncol(data))`. To compute the mutual information between two random vector list the dimensions of each vector. |
| `k` | Order of the local kNN bandwidth selection. |
| `tr` | Order of truncation (number of neighbors to include in the local density estimation). |

## References

Gao, W., Oh, S., & Viswanath, P. (2017). Density functional estimators with k-nearest neighbor bandwidths. IEEE International Symposium on Information Theory - Proceedings, 1, 1351–1355.

## Examples

```
set.seed(123)
x <- rnorm(1000)
y <- x + rnorm(1000)
lnn_mi(cbind(x,y),c(1,1))
```

## nearest_neighbors *Compute Nearest Neighbors*

### Description

Computes the nearest neighbor distances and indices of a sample using the infinite norm.

### Usage

```
nearest_neighbors(data, k)
```

### Arguments

| | |
|---|---|
| data | Matrix of sample observations, each row is an observation. |
| k | Neighborhood order. |

### Details

Nearest neighbors are computed using the brute-force method.

### Value

List of distances and indices of the k-nearest neighbors of each point in `data`.

### Examples

```
X <- cbind(1:10)
nearest_neighbors(X,3)

set.seed(123)
X <- cbind(runif(100),runif(100))
plot(X,pch=20)
points(X[3,1],X[3,2],col='blue',pch=19, cex=1.5)
nn <- nearest_neighbors(X,5)
a = X[nn$nn_inds[3,-1],1]
b = X[nn$nn_inds[3,-1],2]
points(a,b,col='red',pch=19, cex=1.5)
```

`optimize_mse` *Optimize MSE of LNC Estimator*

## Description

Gaussian process (GP) optimization is used to minimize the MSE of the LNC estimator with respect to the non-uniformity threshold parameter `alpha`. A normal distribution with compound-symmetric covariance is used as a reference distribution to optimize the MSE of LNC with respect to.

## Usage

```
optimize_mse(rho, N, M, d, k, lower = -10, upper = -1e-10,
  num_iter = 10, init_size = 20, cluster = NULL, verbose = TRUE)
```

## Arguments

| | |
|---|---|
| `rho` | Reference correlation. |
| `N` | Sample size. |
| `M` | Number of replications. |
| `d` | Dimension. |
| `k` | Neighborhood order. |
| `lower` | Lower bound for optimization. |
| `upper` | Upper bound for optimization. |
| `num_iter` | Number of iterations of GP optimization. |
| `init_size` | Number of initial evaluation to estimating GP. |
| `cluster` | A `parallel` cluster object. |
| `verbose` | If `TRUE` then print runtime diagnostic output. |

## Details

The package `tgp` is used to fit a treed-GP to the MSE estimates of LNC. A treed-GP is used because the MSE of LNC with respect to `alpha` exhibits clear non-stationarity. A treed-GP is able to identify the function's different correlation lengths which improves optimization.

`rmi` *Mutual Information Estimators*

## Description

The `rmi` package offers a collection of mutual information estimators based on k-Nearest Neighbor and local density estimators. Currently, `rmi` provides the Kraskov et al. algorithm (KSG) 1 and 2, Local Non-uniformity Corrected (LNC) KSG, and the Local Nearest Neighbor (LNN) estimator. More estimators and examples will be incorporated in the future.

## References

Gao, S., Ver Steeg G., & Galstyan A. (2015). Efficient estimation of mutual information for strongly dependent variables. Artificial Intelligence and Statistics: 277-286.

Gao, W., Oh, S., & Viswanath, P. (2017). Density functional estimators with k-nearest neighbor bandwidths. IEEE International Symposium on Information Theory - Proceedings, 1, 1351–1355.

Kraskov, A., Stogbauer, H., & Grassberger, P. (2004). Estimating mutual information. Physical review E 69(6): 066138.

## Author(s)

Isaac Michaud

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