

Package ‘RenyiEntropy’

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Type Package

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Description Provides functions to compute Shannon entropy, Renyi entropy, Tsallis entropy, and related extropy measures for discrete probability distributions. Includes joint and conditional entropy, KL divergence, Jensen-Shannon divergence, cross-entropy, normalized entropy, and Renyi extropy (including the conditional and maximum forms). All measures use the natural logarithm (nats). Useful for information theory, statistics, and machine learning applications.

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conditional_entropy	<i>Conditional Entropy</i>
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Description

Computes the conditional Shannon entropy $H(Y | X)$ for two discrete random variables given their joint probability matrix.

Usage

```
conditional_entropy(joint_matrix)
```

Arguments

`joint_matrix` A numeric matrix of joint probabilities, where entry (i, j) gives $P(X = i, Y = j)$. All entries must be non-negative and the matrix must sum to 1. Must not contain NA or NaN values.

Details

The conditional entropy is computed via the chain rule:

$$H(Y | X) = H(X, Y) - H(X)$$

where $H(X, Y)$ is the joint entropy and $H(X)$ is the marginal entropy of X (obtained by summing over rows of `joint_matrix`).

The conditional entropy satisfies $0 \leq H(Y | X) \leq H(Y)$, with equality on the right when X and Y are independent.

Value

A single non-negative numeric value giving the conditional entropy $H(Y | X)$ in nats.

See Also

[joint_entropy\(\)](#), [shannon_entropy\(\)](#), [conditional_renyi_extropy\(\)](#)

Examples

```
# 2 x 2 joint distribution
Pxy <- matrix(c(0.2, 0.3, 0.1, 0.4), nrow = 2, byrow = TRUE)
conditional_entropy(Pxy)

# Independent variables: H(Y|X) = H(Y)
px <- c(0.4, 0.6)
py <- c(0.3, 0.7)
Pxy_indep <- outer(px, py)
conditional_entropy(Pxy_indep)
shannon_entropy(py)
```

conditional_renyi_extropy

Conditional Renyi Entropy

Description

Computes the conditional Renyi entropy $J_q(Y | X)$ for two discrete random variables given their joint probability matrix.

Usage

```
conditional_renyi_extropy(Pxy, q)
```

Arguments

Pxy	A numeric matrix representing the joint probability distribution, where entry (i, j) gives $P(X = i, Y = j)$. Rows correspond to values of X and columns to values of Y . All entries must be non-negative and the matrix must sum to 1. Must not contain NA or NaN values.
q	A single positive numeric value giving the Renyi order parameter. Must satisfy $q > 0$. When $ q - 1 < 10^{-8}$, the limiting (Shannon) conditional entropy is returned.

Details

The conditional Renyi entropy is defined via the chain rule:

$$J_q(Y | X) = J_q(X, Y) - J_q(X)$$

where $J_q(\cdot)$ denotes the Renyi entropy computed on the joint and marginal distributions respectively.

As $q \rightarrow 1$, this converges to the conditional Shannon entropy.

Value

A single numeric value giving the conditional Renyi entropy $J_q(Y | X)$ in nats.

See Also

[renyi_entropy\(\)](#), [conditional_entropy\(\)](#), [max_renyi_entropy\(\)](#)

Examples

```
# 2 x 2 joint distribution
Pxy <- matrix(c(0.2, 0.3, 0.1, 0.4), nrow = 2, byrow = TRUE)
conditional_renyi_entropy(Pxy, q = 2)

# Limiting case q -> 1 (Shannon conditional entropy)
conditional_renyi_entropy(Pxy, q = 1 + 1e-9)

# 3 x 3 joint distribution
Pxy3 <- matrix(c(0.1, 0.05, 0.15, 0.05, 0.2, 0.1, 0.1, 0.15, 0.1),
               nrow = 3, byrow = TRUE)
conditional_renyi_entropy(Pxy3, q = 2)
```

cross_entropy

Cross-Entropy

Description

Computes the cross-entropy between a true probability distribution P and an approximating distribution Q .

Usage

```
cross_entropy(p, q)
```

Arguments

- p** A numeric vector of probabilities representing the true (reference) distribution. Elements must lie in $[0, 1]$, sum to 1, contain at least 2 elements, and must not contain NA or NaN values.
- q** A numeric vector of probabilities representing the approximating distribution. Must be the same length as **p**, with elements in $[0, 1]$, summing to 1, and must not contain NA or NaN values.

Details

The cross-entropy is defined as:

$$H(P, Q) = - \sum_{i=1}^n p_i \log q_i$$

Terms where $p_i = 0$ are omitted. If $q_i = 0$ but $p_i > 0$, q_i is replaced with 10^{-15} and a warning is emitted.

Cross-entropy relates to KL divergence via: $H(P, Q) = H(P) + D_{\text{KL}}(P||Q)$.

Value

A single non-negative numeric value giving the cross-entropy $H(P, Q)$ in nats.

See Also

[kl_divergence\(\)](#), [js_divergence\(\)](#), [shannon_entropy\(\)](#)

Examples

```
p <- c(0.2, 0.5, 0.3)
q <- c(0.3, 0.4, 0.3)
cross_entropy(p, q)

# When P == Q, cross-entropy equals Shannon entropy
cross_entropy(p, p)
shannon_entropy(p)
```

 extropy

Classical Entropy

Description

Computes the classical extropy for a discrete probability distribution.

Usage

```
extropy(p)
```

Arguments

`p` A numeric vector of probabilities (p_1, \dots, p_n) , where each element must lie in $[0, 1]$ and the elements must sum to 1. The vector must contain at least 2 elements and must not contain NA or NaN values.

Details

The classical extropy is defined as:

$$J(\mathbf{p}) = - \sum_{i=1}^n (1 - p_i) \log(1 - p_i)$$

Terms where $1 - p_i = 0$ (i.e., $p_i = 1$) are omitted to avoid $\log 0$. Extropy is the dual complement of entropy and measures information in terms of the complementary probabilities.

Value

A single non-negative numeric value giving the classical extropy (in nats).

See Also

[shannon_entropy\(\)](#), [renyi_extropy\(\)](#), [shannon_extropy\(\)](#)

Examples

```
# Three-outcome distribution
p <- c(0.2, 0.5, 0.3)
extropy(p)

# Uniform distribution
extropy(rep(0.25, 4))

# Binary distribution
extropy(c(0.7, 0.3))
```

joint_entropy

Joint Entropy

Description

Computes the joint Shannon entropy for a bivariate discrete distribution specified by a joint probability matrix.

Usage

```
joint_entropy(joint_matrix)
```

Arguments

`joint_matrix` A numeric matrix of joint probabilities, where entry (i, j) gives $P(X = i, Y = j)$. All entries must be non-negative and the matrix must sum to 1. Must not contain NA or NaN values.

Details

The joint entropy is defined as:

$$H(X, Y) = - \sum_{i,j} P(X = i, Y = j) \log P(X = i, Y = j)$$

with the convention that $0 \log 0 = 0$. This satisfies $H(X, Y) \geq \max(H(X), H(Y))$ and the chain rule $H(X, Y) = H(X) + H(Y | X)$.

Value

A single non-negative numeric value giving the joint entropy $H(X, Y)$ in nats.

See Also

[conditional_entropy\(\)](#), [shannon_entropy\(\)](#)

Examples

```
# 2 x 2 joint distribution
Pxy <- matrix(c(0.2, 0.3, 0.1, 0.4), nrow = 2, byrow = TRUE)
joint_entropy(Pxy)

# Independent distributions: H(X,Y) = H(X) + H(Y)
px <- c(0.4, 0.6)
py <- c(0.3, 0.7)
Pxy_indep <- outer(px, py)
joint_entropy(Pxy_indep)
shannon_entropy(px) + shannon_entropy(py)
```

js_divergence

Jensen-Shannon Divergence

Description

Computes the Jensen-Shannon (JS) divergence between two probability distributions.

Usage

```
js_divergence(p, q)
```

Arguments

- p** A numeric vector of probabilities. Elements must lie in $[0, 1]$, sum to 1, contain at least 2 elements, and must not contain NA or NaN values.
- q** A numeric vector of probabilities. Must be the same length as **p**, with elements in $[0, 1]$, summing to 1, and must not contain NA or NaN values.

Details

The JS divergence is defined as:

$$\text{JSD}(P\|Q) = \frac{1}{2}D_{\text{KL}}(P\|M) + \frac{1}{2}D_{\text{KL}}(Q\|M)$$

where $M = (P + Q)/2$ is the mixture distribution and D_{KL} is the KL divergence.

Unlike [kl_divergence\(\)](#), the JS divergence is symmetric and always finite (even when one distribution has zero entries). Its square root is a metric.

Value

A single non-negative numeric value giving the Jensen-Shannon divergence in nats. The value is bounded in $[0, \log 2]$.

See Also

[kl_divergence\(\)](#), [cross_entropy\(\)](#)

Examples

```
p <- c(0.2, 0.5, 0.3)
q <- c(0.3, 0.4, 0.3)
js_divergence(p, q)

# Symmetry: JSD(P, Q) == JSD(Q, P)
js_divergence(q, p)

# JSD is 0 when P == Q
js_divergence(p, p)

# JSD <= log(2) for any two distributions
js_divergence(c(1, 0), c(0, 1))
log(2)
```

kl_divergence	<i>Kullback-Leibler Divergence</i>
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Description

Computes the Kullback-Leibler (KL) divergence from distribution Q to distribution P .

Usage

```
kl_divergence(p, q)
```

Arguments

p	A numeric vector of probabilities representing the true (reference) distribution. Elements must lie in $[0, 1]$, sum to 1, contain at least 2 elements, and must not contain NA or NaN values.
q	A numeric vector of probabilities representing the approximating distribution. Must be the same length as p, with elements in $[0, 1]$, summing to 1, and must not contain NA or NaN values.

Details

The KL divergence is defined as:

$$D_{\text{KL}}(P\|Q) = \sum_{i=1}^n p_i \log \frac{p_i}{q_i}$$

Terms where $p_i = 0$ are omitted (convention $0 \log 0 = 0$). If $q_i = 0$ but $p_i > 0$ the divergence is technically infinite; this function replaces such q_i with 10^{-15} and emits a warning.

Note that KL divergence is not symmetric: $D_{\text{KL}}(P\|Q) \neq D_{\text{KL}}(Q\|P)$ in general. For a symmetric measure see [js_divergence\(\)](#).

Value

A single non-negative numeric value giving the KL divergence $D_{\text{KL}}(P\|Q)$ in nats.

See Also

[js_divergence\(\)](#), [cross_entropy\(\)](#), [shannon_entropy\(\)](#)

Examples

```
p <- c(0.2, 0.5, 0.3)
q <- c(0.3, 0.4, 0.3)
kl_divergence(p, q)

# KL divergence is zero when P == Q
kl_divergence(p, p)
```

```
# Asymmetry: KL(P||Q) != KL(Q||P)
kl_divergence(p, q)
kl_divergence(q, p)
```

max_renyi_extropy *Maximum Renyi Entropy*

Description

Computes the maximum Renyi entropy, which is attained by the uniform discrete distribution over n outcomes.

Usage

```
max_renyi_extropy(n)
```

Arguments

n A single integer value giving the number of outcomes. Must satisfy $n \geq 2$.

Details

For a uniform distribution $p_i = 1/n$, the maximum Renyi entropy is:

$$\max_{\mathbf{p}} J_q(\mathbf{p}) = (n - 1) \log \left(\frac{n}{n - 1} \right)$$

Remarkably, this value is independent of the Renyi parameter q (for any $q > 0$, $q \neq 1$).

Value

A single positive numeric value giving the maximum Renyi entropy.

See Also

[renyi_extropy\(\)](#), [conditional_renyi_extropy\(\)](#)

Examples

```
# Maximum Renyi entropy for n = 3 outcomes
max_renyi_extropy(3)

# For n = 10 outcomes
max_renyi_extropy(10)

# Verify against renyi_extropy() with uniform distribution
max_renyi_extropy(4)
renyi_extropy(rep(0.25, 4), q = 2)
```

normalized_entropy	<i>Normalized Shannon Entropy</i>
--------------------	-----------------------------------

Description

Computes the normalized Shannon entropy (also called relative entropy or efficiency) for a discrete probability distribution.

Usage

```
normalized_entropy(p)
```

Arguments

p A numeric vector of probabilities (p_1, \dots, p_n) , where each element must lie in $[0, 1]$ and the elements must sum to 1. The vector must contain at least 2 elements and must not contain NA or NaN values.

Details

The normalized entropy is defined as:

$$H_{\text{norm}}(\mathbf{p}) = \frac{H(\mathbf{p})}{\log n}$$

where $H(\mathbf{p})$ is the Shannon entropy and n is the number of outcomes. The result equals 0 for a degenerate distribution and 1 for a uniform distribution.

Value

A single numeric value in $[0, 1]$ giving the ratio of the Shannon entropy to its maximum possible value $\log n$.

See Also

[shannon_entropy\(\)](#)

Examples

```
# Uniform distribution: normalized entropy = 1
normalized_entropy(rep(0.25, 4))

# Degenerate distribution: normalized entropy = 0
normalized_entropy(c(1, 0, 0))

# Intermediate distribution
normalized_entropy(c(0.2, 0.5, 0.3))
```

renyi_entropy

Renyi Entropy

Description

Computes the Renyi entropy for a discrete probability distribution and order parameter q .

Usage

```
renyi_entropy(p, q)
```

Arguments

- p** A numeric vector of probabilities (p_1, \dots, p_n) , where each element must lie in $[0, 1]$ and the elements must sum to 1. The vector must contain at least 2 elements and must not contain NA or NaN values.
- q** A single positive numeric value giving the Renyi order parameter. Must satisfy $q > 0$. When q is numerically close to 1 (within 10^{-8}), the Shannon entropy is returned instead.

Details

The Renyi entropy of order q is defined as:

$$H_q(\mathbf{p}) = \frac{1}{1-q} \log \left(\sum_{i=1}^n p_i^q \right)$$

For $q \rightarrow 1$, this reduces to the Shannon entropy:

$$H(\mathbf{p}) = - \sum_{i=1}^n p_i \log p_i$$

The function detects when $|q - 1| < 10^{-8}$ and returns the Shannon entropy in that case to avoid numerical issues near the singularity.

Special cases: H_0 is the log of the support size (Hartley entropy), H_2 is the collision entropy, and H_∞ is the min-entropy.

Value

A single numeric value giving the Renyi entropy (in nats).

See Also

[shannon_entropy\(\)](#), [tsallis_entropy\(\)](#), [renyi_extropy\(\)](#)

Examples

```

p <- c(0.2, 0.5, 0.3)

# Renyi entropy for q = 2 (collision entropy)
renyi_entropy(p, 2)

# Renyi entropy for q = 0.5
renyi_entropy(p, 0.5)

# q near 1 returns Shannon entropy
renyi_entropy(p, 1 + 1e-9)

# Explicit Shannon entropy for comparison
shannon_entropy(p)

```

renyi_extropy	<i>Renyi Extropy</i>
---------------	----------------------

Description

Computes the Renyi extropy for a discrete probability distribution and Renyi order parameter q .

Usage

```
renyi_extropy(p, q)
```

Arguments

p	A numeric vector of probabilities (p_1, \dots, p_n) , where each element must lie in $[0, 1]$ and the elements must sum to 1. The vector must contain at least 2 elements and must not contain NA or NaN values.
q	A single positive numeric value giving the Renyi order parameter. Must satisfy $q > 0$. When $ q-1 < 10^{-8}$, the classical extropy (Shannon extropy) is returned instead.

Details

The Renyi extropy of order q is defined as:

$$J_q(\mathbf{p}) = \frac{-(n-1) \log(n-1) + (n-1) \log(\sum_{i=1}^n (1-p_i)^q)}{1-q}$$

where n is the number of outcomes.

For $q \rightarrow 1$, the formula reduces to the classical (Shannon) extropy:

$$J(\mathbf{p}) = - \sum_{i=1}^n (1-p_i) \log(1-p_i)$$

For $n = 2$, the Renyi extropy coincides with the Renyi entropy.

Value

A single numeric value giving the Renyi extropy (in nats).

See Also

[extropy\(\)](#), [renyi_entropy\(\)](#), [conditional_renyi_extropy\(\)](#), [max_renyi_extropy\(\)](#)

Examples

```
p <- c(0.2, 0.5, 0.3)

# Renyi extropy for q = 2
renyi_extropy(p, 2)

# For q near 1, returns classical extropy
renyi_extropy(p, 1 + 1e-9)

# Compare with extropy() at the limiting case
extropy(p)

# Binary distribution (n = 2): Renyi extropy equals Renyi entropy
renyi_extropy(c(0.4, 0.6), 2)
renyi_entropy(c(0.4, 0.6), 2)
```

shannon_entropy

Shannon Entropy

Description

Computes the Shannon entropy for a discrete probability distribution.

Usage

```
shannon_entropy(p)
```

Arguments

p A numeric vector of probabilities (p_1, \dots, p_n) , where each element must lie in $[0, 1]$ and the elements must sum to 1. The vector must contain at least 2 elements and must not contain NA or NaN values.

Details

The Shannon entropy is defined as:

$$H(\mathbf{p}) = - \sum_{i=1}^n p_i \log(p_i)$$

with the convention that $0 \log 0 = 0$ (terms where $p_i = 0$ contribute zero). The logarithm used is the natural logarithm, so the result is in nats.

Shannon entropy is the limiting case of the Renyi entropy as $q \rightarrow 1$ and equals zero if and only if the distribution is degenerate. It is maximised by the uniform distribution, where $H = \log n$.

Value

A single non-negative numeric value giving the Shannon entropy measured in nats (natural-logarithm base).

See Also

[renyi_entropy\(\)](#), [tsallis_entropy\(\)](#), [extropy\(\)](#), [normalized_entropy\(\)](#)

Examples

```
# Three-outcome distribution
p <- c(0.2, 0.5, 0.3)
shannon_entropy(p)

# Uniform distribution -- maximum entropy equals log(n)
shannon_entropy(rep(0.25, 4))

# Degenerate distribution -- entropy equals 0
shannon_entropy(c(1, 0, 0))
```

shannon_extropy	<i>Shannon Extropy</i>
-----------------	------------------------

Description

Computes the Shannon extropy for a discrete probability distribution.

Usage

```
shannon_extropy(p)
```

Arguments

p A numeric vector of probabilities (p_1, \dots, p_n) , where each element must lie in $[0, 1]$ and the elements must sum to 1. The vector must contain at least 2 elements and must not contain NA or NaN values.

Details

Shannon extropy is defined as:

$$J(\mathbf{p}) = - \sum_{i=1}^n (1 - p_i) \log(1 - p_i)$$

Terms where $p_i = 1$ are treated as contributing zero (using the convention $0 \log 0 = 0$).

This function is an alias for [extropy\(\)](#); both compute the same quantity. It is retained for naming consistency with [shannon_entropy\(\)](#).

Value

A single non-negative numeric value giving the Shannon extropy (in nats).

See Also

[extropy\(\)](#), [shannon_entropy\(\)](#), [renyi_extropy\(\)](#)

Examples

```
p <- c(0.2, 0.5, 0.3)
shannon_extropy(p)

# Identical to extropy()
extropy(p)

# Uniform distribution
shannon_extropy(rep(1/3, 3))
```

tsallis_entropy	<i>Tsallis Entropy</i>
-----------------	------------------------

Description

Computes the Tsallis entropy for a discrete probability distribution and order parameter q .

Usage

```
tsallis_entropy(p, q)
```

Arguments

- p A numeric vector of probabilities (p_1, \dots, p_n) , where each element must lie in $[0, 1]$ and the elements must sum to 1. The vector must contain at least 2 elements and must not contain NA or NaN values.
- q A single positive numeric value giving the Tsallis order parameter. Must satisfy $q > 0$. When $|q - 1| < 10^{-8}$, the Shannon entropy is returned.

Details

The Tsallis entropy of order q is defined as:

$$S_q(\mathbf{p}) = \frac{1 - \sum_{i=1}^n p_i^q}{q - 1}$$

For $q \rightarrow 1$, this reduces to the Shannon entropy:

$$H(\mathbf{p}) = - \sum_{i=1}^n p_i \log p_i$$

The Tsallis entropy is non-extensive and is widely used in non-equilibrium statistical mechanics and complex systems.

Value

A single non-negative numeric value giving the Tsallis entropy.

See Also

[shannon_entropy\(\)](#), [renyi_entropy\(\)](#)

Examples

```
p <- c(0.2, 0.5, 0.3)

# Tsallis entropy for q = 2
tsallis_entropy(p, 2)

# Tsallis entropy for q = 0.5
tsallis_entropy(p, 0.5)

# As q -> 1, converges to Shannon entropy
tsallis_entropy(p, 1 + 1e-9)
shannon_entropy(p)
```

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