

# Package: BayesCVI (via r-universe)

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**Type** Package

**Title** Bayesian Cluster Validity Index

**Version** 1.0.1

**Imports** e1071, mclust, ggplot2, UniversalCVI

**Description** Algorithms for computing and generating plots with and without error bars for Bayesian cluster validity index (BCVI) (O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, Computational Statistics & Data Analysis, 202, 108053, 2025. <[doi:10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)>) based on several underlying cluster validity indexes (CVIs) including Calinski-Harabasz, Chou-Su-Lai, Davies-Bouldin, Dunn, Pakhira-Bandyopadhyay-Maulik, Point biserial correlation, the score function, Starczewski, and Wiroonsri indices for hard clustering, and Correlation Cluster Validity, the generalized C, HF, KWON, KWON2, Modified Pakhira-Bandyopadhyay-Maulik, Pakhira-Bandyopadhyay-Maulik, Tang, Wiroonsri-Preedasawakul, Wu-Li, and Xie-Beni indices for soft clustering. The package is compatible with K-means, fuzzy C means, EM clustering, and hierarchical clustering (single, average, and complete linkage). Though BCVI is compatible with any underlying existing CVIs, we recommend users to use either WI or WP as the underlying CVI.

**License** GPL (>= 3)

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**Author** Nathakhun Wiroonsri [aut]  
(<<https://orcid.org/0000-0003-2167-9641>>), Onthada  
Preedasawakul [cre, aut]  
(<<https://orcid.org/0000-0002-4186-3158>>)

**Maintainer** Onthada Preedasawakul <o.preedasawakul@gmail.com>

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B1\_data

*B1 Artificial Dataset*

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**Description**

A 2-dimensional dataset from Wiroonsri and Preedasawakul (2024) generated from 1 Gaussian and 1 Uniform distributions labeled as 1–2.

**Usage**

B1\_data

**Format**

A data frame with 5500 data points and 3 variables

x Numeric values generated from Gaussian and Uniform distributions

y Numeric values generated from Gaussian and Uniform distributions

label Categorical labels 1,2

**Author(s)**

Nathakhun Wiroonsri and Onthada Preedasawakul

**References**

O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, Computational Statistics & Data Analysis, 202, 108053, 2025. [doi:10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

**See Also**

[B2\\_data](#), [B3\\_data](#), [B\\_WP.IDX](#), [B\\_Wvalid](#), [B\\_XB.IDX](#)

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B2\_data

*B2 Artificial Dataset*

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**Description**

A 2-dimensional dataset from Wiroonsri and Preedasawakul (2024) generated from 5 different Gaussian distributions labeled as 1–5.

**Usage**

B2\_data

**Format**

A data frame with 850 data points and 3 variables  
x Numeric values generated from Gaussian distributions  
y Numeric values generated from Gaussian distributions  
label1 Categorical labels 1,2,3,4,5

**Author(s)**

Nathakhun Wiroonsri and Onthada Preedasawakul

**References**

O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, Computational Statistics & Data Analysis, 202, 108053, 2025. doi:[10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

**See Also**

[B1\\_data](#), [B3\\_data](#), [B\\_WP.IDX](#), [B\\_Wvalid](#), [B\\_XB.IDX](#)

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B3\_data

*B3 Artificial Dataset*

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**Description**

A 2-dimensional dataset from Wiroonsri and Preedasawakul (2024) generated from 5 different Gaussian distributions labeled as 1-5.

**Usage**

B3\_data

**Format**

A data frame with 2300 data points and 3 variables  
x Numeric values generated from Gaussian distributions  
y Numeric values generated from Gaussian distributions  
label1 Categorical labels 1,2,3,4,5

**Author(s)**

Nathakhun Wiroonsri and Onthada Preedasawakul

**References**

O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, Computational Statistics & Data Analysis, 202, 108053, 2025. doi:[10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

**See Also**

[B2\\_data](#), [B4\\_data](#), [B\\_WP.IDX](#), [B\\_Wvalid](#), [B\\_XB.IDX](#)

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B4\_data

*B4 Artificial Dataset*

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**Description**

A 2-dimensional dataset from Wiroonsri and Preedasawakul (2024) generated from 6 different Gaussian distributions labeled as 1-6.

**Usage**

B4\_data

**Format**

A data frame with 740 data points and 3 variables

x Numeric values generated from Gaussian distributions

y Numeric values generated from Gaussian distributions

label Categorical labels 1,2,3,4,5,6

**Author(s)**

Nathakhun Wiroonsri and Onthada Preedasawakul

**References**

O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, Computational Statistics & Data Analysis, 202, 108053, 2025. [doi:10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

**See Also**

[B3\\_data](#), [B5\\_data](#), [B\\_WP.IDX](#), [B\\_Wvalid](#), [B\\_XB.IDX](#)

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B5\_data

*B5 Artificial Dataset*

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### Description

A 2-dimensional dataset from Wiroonsri and Preedasawakul (2024) generated from 7 different Gaussian and 2 Uniform distributions labeled as 1-9.

### Usage

B5\_data

### Format

A data frame with 1820 data points and 3 variables

x Numeric values generated from Gaussian and Uniform distributions

y Numeric values generated from Gaussian and Uniform distributions

label Categorical labels 1,2,3,4,5,6,7,8,9

### Author(s)

Nathakhun Wiroonsri and Onthada Preedasawakul

### References

O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, Computational Statistics & Data Analysis, 202, 108053, 2025. [doi:10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

### See Also

[B4\\_data](#), [B6\\_data](#), [B\\_WP.IDX](#), [B\\_Wvalid](#), [B\\_XB.IDX](#)

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B6\_data

*B6 Artificial Dataset*

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### Description

A 2-dimensional dataset from Wiroonsri and Preedasawakul (2024) generated from 3 different Gaussian and 2 Uniform distributions labeled as 1-5.

### Usage

B6\_data

**Format**

A data frame with 1000 data points and 3 variables

x Numeric values generated from Gaussian and Uniform distributions

y Numeric values generated from Gaussian and Uniform distributions

label Categorical labels 1,2,3,4,5

**Author(s)**

Nathakhun Wiroonsri and Onthada Preedasawakul

**References**

O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, Computational Statistics & Data Analysis, 202, 108053, 2025. doi:[10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

**See Also**

[B5\\_data](#), [B7\\_data](#), [B\\_WP.IDX](#), [B\\_Wvalid](#), [B\\_XB.IDX](#)

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B7\_data

*B7 Artificial Dataset*

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**Description**

A 2-dimensional dataset from Wiroonsri and Preedasawakul (2024) generated from 3 different Gaussian and 2 Uniform distributions labeled as 1-5.

**Usage**

B7\_data

**Format**

A data frame with 800 data points and 3 variables

x Numeric values generated from Gaussian and Uniform distributions

y Numeric values generated from Gaussian and Uniform distributions

label Categorical labels 1,2,3,4,5

**Author(s)**

Nathakhun Wiroonsri and Onthada Preedasawakul

**References**

O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, Computational Statistics & Data Analysis, 202, 108053, 2025. doi:[10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

**See Also**

[B6\\_data](#), [B1\\_data](#), [B\\_WP.IDX](#), [B\\_Wvalid](#), [B\\_XB.IDX](#)

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BayesCVIs

*Bayesian cluster validity index*

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**Description**

Compute Bayesian cluster validity index (BCVI) from two to kmax groups using an underlying cluster validity index (CVI) and Dirichlet prior parameters of the user's choice. The full detail of BCVI can be found in the paper Wiroonsri and Preedasawakul (2024).

**Usage**

```
BayesCVIs(CVI, n, kmax, opt.pt, alpha = "default", mult.alpha = 1/2)
```

**Arguments**

CVI	the CVI values for k from 2 to kmax to be used as the underlying index for computing BCVI.
n	a number of data point.
kmax	a maximum number of clusters to be considered.
opt.pt	a character string indicating whether the maximum or the minimum of CVI specifies the optimal number of groups ("min" or "max").
alpha	Dirichlet prior parameters $\alpha_2, \dots, \alpha_k$ where $\alpha_k$ is the parameter corresponding to "the probability of having k groups" (selecting each $\alpha_k$ between 0 to 30 is recommended and using the other parameter mult.alpha to be its multiplier. The default is "default").
mult.alpha	the power $s$ from $n^s$ to be multiplied to the Dirichlet prior parameters alpha (selecting mult.alpha in $[\theta, 1)$ is recommended). The default is $\frac{1}{2}$ .

**Details**

BCVI is defined as follows. Let

$$r_k(\mathbf{x}) = \frac{\max_j \mathbf{CVI}(j) - \mathbf{CVI}(k)}{\sum_{i=2}^K (\max_j \mathbf{CVI}(j) - \mathbf{CVI}(i))}$$

for a CVI such that the smallest value indicates the optimal number of clusters and

$$r_k(\mathbf{x}) = \frac{\mathbf{CVI}(k) - \min_j \mathbf{CVI}(j)}{\sum_{i=2}^K (\mathbf{CVI}(i) - \min_j \mathbf{CVI}(j))}$$

for a CVI such that the largest value indicates the optimal number of clusters. Assume that

$$f(\mathbf{x}|\mathbf{p}) = C(\mathbf{p}) \prod_{k=2}^K p_k^{nr_k(x)}$$



represents the conditional probability density function of the dataset given  $\mathbf{p}$ , where  $C(\mathbf{p})$  is the normalizing constant. Assume further that  $\mathbf{p}$  follows a Dirichlet prior distribution with parameters  $\boldsymbol{\alpha} = (\alpha_2, \dots, \alpha_K)$ . The posterior distribution of  $\mathbf{p}$  still remains a Dirichlet distribution with parameters  $(\alpha_2 + nr_2(\mathbf{x}), \dots, \alpha_K + nr_K(\mathbf{x}))$ .

The BCVI is then defined as

$$BCVI(k) = E[p_k | \mathbf{x}] = \frac{\alpha_k + nr_k(\mathbf{x})}{\alpha_0 + n}$$

where  $\alpha_0 = \sum_{k=2}^K \alpha_k$ .

The variance of  $p_k$  can be computed as

$$Var(p_k | \mathbf{x}) = \frac{(\alpha_k + nr_k(x))(\alpha_0 + n - \alpha_k - nr_k(x))}{(\alpha_0 + n)^2(\alpha_0 + n + 1)}.$$

### Value

BCVI	the dataframe where the first and the second columns are the number of groups $k$ and $BCVI(k)$ , respectively, for $k$ from 2 to $kmax$ .
VAR	the data frame where the first and the second columns are the number of groups $k$ and the variance of $p_k$ , respectively, for $k$ from 2 to $kmax$ .
CVI	the data frame where the first and the second columns are the number of groups $k$ and the original $CVI(k)$ , respectively, for $k$ from 2 to $kmax$ .
opt.pt	a character string indicating whether the maximum or the minimum of CVI specifies the optimal number of groups ("min" or "max") that user select.

### Author(s)

Nathakhun Wiroonsri and Onthada Preedasawakul

### References

O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, Computational Statistics & Data Analysis, 202, 108053, 2025. doi:10.1016/j.csda.2024.108053

### See Also

[B2\\_data](#), [B\\_TANG.IDX](#), [B\\_WP.IDX](#), [B\\_Wvalid](#), [B\\_DB.IDX](#)

### Examples

```
# install a package for computing an underlying CVI
# install.packages("UniversalCVI")

library(UniversalCVI)
library(BayesCVI)

data = R1_data[, -3]
```

```

# Compute WP index by WP.IDX using default gamma
FCM.WP = WP.IDX(scale(data), cmax = 10, cmin = 2, corr = 'pearson', method = 'FCM', fzm = 2,
                 iter = 100, nstart = 20, NCstart = TRUE)

# WP.IDX values
result = FCM.WP$WP$WPI

aalpha = c(20,20,20,5,5,5,0.5,0.5,0.5)
B.WP = BayesCVIs(CVI = result,
                 n = nrow(data),
                 kmax = 10,
                 opt.pt = "max",
                 alpha = aalpha,
                 mult.alpha = 1/2)

# plot the BCVI

pplot = plot_BCVI(B.WP)
pplot$plot_index
pplot$plot_BCVI
pplot$error_bar_plot

```

---

B\_CC.V.IDX

*BCVI-Correlation Cluster Validity (CCV) index*


---

### Description

Compute Bayesian cluster validity index (BCVI) from two to kmax groups using the pearson correlation cluster validity (CCVP) and/or the spearman's (rho) correlation cluster validity (CCVS) as the underling cluster validity index (CVI) with the user's selected Dirichlet prior parameters. The full detail of BCVI can be found in the paper Wiroonsri and Preedasawakul (2024).

### Usage

```

B_CC.V.IDX(x, kmax, indexlist = "all", method = "FCM", fzm = 2,
           iter = 100, nstart = 20, alpha = "default", mult.alpha = 1/2)

```

### Arguments

x	a numeric data frame or matrix where each column is a variable to be used for cluster analysis and each row is a data point.
kmax	a maximum number of clusters to be considered.
indexlist	a character string indicating which The generalized C index be computed ("all", "CCVP", "CCVS"). More than one indexes can be selected.
method	a character string indicating which clustering method to be used ("FCM" or "EM"). The default is "FCM".

fzm	a number greater than 1 giving the degree of fuzzification for method = "FCM". The default is 2.
iter	a maximum number of iterations for method = "FCM". The default is 100.
nstart	a maximum number of initial random sets for FCM for method = "FCM". The default is 20.
alpha	Dirichlet prior parameters $\alpha_2, \dots, \alpha_k$ where $\alpha_k$ is the parameter corresponding to "the probability of having k groups" (selecting each $\alpha_k$ between 0 to 30 is recommended and using the other parameter mult.alpha to be its multiplier. The default is "default".)
mult.alpha	the power $s$ from $n^s$ to be multiplied to the Dirichlet prior parameters alpha (selecting mult.alpha in $[\theta, 1)$ is recommended). The default is $\frac{1}{2}$ .

### Details

BCVI-CCV is defined as follows. Let

$$r_k(\mathbf{x}) = \frac{\text{CVI}(\mathbf{k}) - \min_j \text{CVI}(\mathbf{j})}{\sum_{i=2}^K (\text{CVI}(\mathbf{i}) - \min_j \text{CVI}(\mathbf{j}))}$$

where CVI is either CCVP or CCVS index.

Assume that

$$f(\mathbf{x}|\mathbf{p}) = C(\mathbf{p}) \prod_{k=2}^K p_k^{nr_k(x)}$$

represents the conditional probability density function of the dataset given  $\mathbf{p}$ , where  $C(\mathbf{p})$  is the normalizing constant. Assume further that  $\mathbf{p}$  follows a Dirichlet prior distribution with parameters  $\boldsymbol{\alpha} = (\alpha_2, \dots, \alpha_K)$ . The posterior distribution of  $\mathbf{p}$  still remains a Dirichlet distribution with parameters  $(\alpha_2 + nr_2(\mathbf{x}), \dots, \alpha_K + nr_K(\mathbf{x}))$ .

The BCVI is then defined as

$$BCVI(k) = E[p_k|\mathbf{x}] = \frac{\alpha_k + nr_k(\mathbf{x})}{\alpha_0 + n}$$

where  $\alpha_0 = \sum_{k=2}^K \alpha_k$ .

The variance of  $p_k$  can be computed as

$$Var(p_k|\mathbf{x}) = \frac{(\alpha_k + nr_k(x))(\alpha_0 + n - \alpha_k - nr_k(x))}{(\alpha_0 + n)^2(\alpha_0 + n + 1)}.$$

### Value

BCVI	the dataframe where the first and the second columns are the number of groups k and BCVI(k), respectively, for k from 2 to kmax.
VAR	the data frame where the first and the second columns are the number of groups k and the variance of $p_k$ , respectively, for k from 2 to kmax.
CVI	the data frame where the first and the second columns are the number of groups k and the original CCVP(k) or CCVS(k), respectively, for k from 2 to kmax.

**Author(s)**

Nathakhun Wiroonsri and Onthada Preedasawakul

**References**

M. Popescu, J. C. Bezdek, T. C. Havens and J. M. Keller (2013). "A Cluster Validity Framework Based on Induced Partition Dissimilarity." <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6246717&isnumber=6340245>

O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, Computational Statistics & Data Analysis, 202, 108053, 2025. doi:10.1016/j.csda.2024.108053

**See Also**

[B7\\_data](#), [B\\_TANG.IDX](#), [B\\_XB.IDX](#), [B\\_Wvalid](#), [B\\_DB.IDX](#)

**Examples**

```
library(BayesCVI)

# The data included in this package.
data = B7_data[,1:2]

# alpha
aalpha = c(20,20,20,5,5,5,0.5,0.5,0.5)

B.CCV = B_CCV.IDX(x = scale(data), kmax=10, indexlist = "CCVP", method = "FCM", fzm = 2, iter = 100,
  nstart = 20, alpha = aalpha, mult.alpha = 1/2)

# plot the BCVI-CCVP

pplot = plot_BCVI(B.CCV$CCVP)
pplot$plot_index
pplot$plot_BCVI
pplot$error_bar_plot
```

---

B\_CH.IDX

*BCVI-Calinski-Harabasz (CH) index*

---

**Description**

Compute Bayesian cluster validity index (BCVI) from two to kmax groups using Calinski-Harabasz (CH) as the underlying cluster validity index (CVI) with the user's selected Dirichlet prior parameters. The full detail of BCVI can be found in the paper Wiroonsri and Preedasawakul (2024).

**Usage**

```
B_CH.IDX(x, kmax, method = "kmeans", nstart = 100, alpha = "default", mult.alpha = 1/2)
```

**Arguments**

<code>x</code>	a numeric data frame or matrix where each column is a variable to be used for cluster analysis and each row is a data point.
<code>kmax</code>	a maximum number of clusters to be considered.
<code>method</code>	a character string indicating which clustering method to be used ("kmeans", "hclust_complete", "hclust_average", "hclust_single"). The default is "kmeans".
<code>nstart</code>	a maximum number of initial random sets for kmeans for method = "kmeans". The default is 100.
<code>alpha</code>	Dirichlet prior parameters $\alpha_2, \dots, \alpha_k$ where $\alpha_k$ is the parameter corresponding to "the probability of having k groups" (selecting each $\alpha_k$ between 0 to 30 is recommended and using the other parameter <code>mult.alpha</code> to be its multiplier. The default is "default".
<code>mult.alpha</code>	the power $s$ from $n^s$ to be multiplied to the Dirichlet prior parameters <code>alpha</code> (selecting <code>mult.alpha</code> in $[\theta, 1)$ is recommended). The default is $\frac{1}{2}$ .

**Details**

BCVI-CH is defined as follows. Let

$$r_k(\mathbf{x}) = \frac{\mathbf{CH}(\mathbf{k}) - \min_j \mathbf{CH}(\mathbf{j})}{\sum_{i=2}^K (\mathbf{CH}(\mathbf{i}) - \min_j \mathbf{CH}(\mathbf{j}))}$$

Assume that

$$f(\mathbf{x}|\mathbf{p}) = C(\mathbf{p}) \prod_{k=2}^K p_k^{nr_k(x)}$$

represents the conditional probability density function of the dataset given  $\mathbf{p}$ , where  $C(\mathbf{p})$  is the normalizing constant. Assume further that  $\mathbf{p}$  follows a Dirichlet prior distribution with parameters  $\boldsymbol{\alpha} = (\alpha_2, \dots, \alpha_K)$ . The posterior distribution of  $\mathbf{p}$  still remains a Dirichlet distribution with parameters  $(\alpha_2 + nr_2(\mathbf{x}), \dots, \alpha_K + nr_K(\mathbf{x}))$ .

The BCVI is then defined as

$$BCVI(k) = E[p_k|\mathbf{x}] = \frac{\alpha_k + nr_k(\mathbf{x})}{\alpha_0 + n}$$

where  $\alpha_0 = \sum_{k=2}^K \alpha_k$ .

The variance of  $p_k$  can be computed as

$$Var(p_k|\mathbf{x}) = \frac{(\alpha_k + nr_k(x))(\alpha_0 + n - \alpha_k - nr_k(x))}{(\alpha_0 + n)^2(\alpha_0 + n + 1)}.$$

**Value**

BCVI	the dataframe where the first and the second columns are the number of groups $k$ and $BCVI(k)$ , respectively, for $k$ from 2 to $k_{max}$ .
VAR	the data frame where the first and the second columns are the number of groups $k$ and the variance of $p_k$ , respectively, for $k$ from 2 to $k_{max}$ .
CVI	the data frame where the first and the second columns are the number of groups $k$ and the original $CH(k)$ , respectively, for $k$ from 2 to $k_{max}$ .

**Author(s)**

Nathakhun Wiroonsri and Onthada Preedasawakul

**References**

T. Calinski, J. Harabasz, "A dendrite method for cluster analysis," *Communications in Statistics*, 3, 1-27 (1974).

O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, *Computational Statistics & Data Analysis*, 202, 108053, 2025. [doi:10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

**See Also**

[B2\\_data](#), [B\\_TANG.IDX](#), [B\\_XB.IDX](#), [B\\_Wvalid](#), [B\\_DB.IDX](#)

**Examples**

```
library(BayesCVI)

# The data included in this package.
data = B2_data[,1:2]

# alpha
aalpha = c(5,5,5,20,20,20,0.5,0.5,0.5)

B.CH = B_CH.IDX(x = scale(data), kmax=10, method = "kmeans",
               nstart = 100, alpha = aalpha, mult.alpha = 1/2)

# plot the BCVI

pplot = plot_BCVI(B.CH)
pplot$plot_index
pplot$plot_BCVI
pplot$error_bar_plot
```

B\_CSL.IDX

*BCVI-Chou-Su-Lai (CSL) index***Description**

Compute Bayesian cluster validity index (BCVI) from two to `kmax` groups using Chou-Su-Lai (CSL) as the underlying cluster validity index (CVI) and Dirichlet prior parameters of the user's choice. The full detail of BCVI can be found in the paper Wiroonsri and Preedasawakul (2024).

**Usage**

```
B_CSL.IDX(x, kmax, method = "kmeans", nstart = 100, alpha = "default", mult.alpha = 1/2)
```

**Arguments**

<code>x</code>	a numeric data frame or matrix where each column is a variable to be used for cluster analysis and each row is a data point.
<code>kmax</code>	a maximum number of clusters to be considered.
<code>method</code>	a character string indicating which clustering method to be used ("kmeans", "hclust_complete", "hclust_average", "hclust_single"). The default is "kmeans".
<code>nstart</code>	a maximum number of initial random sets for kmeans for method = "kmeans". The default is 100.
<code>alpha</code>	Dirichlet prior parameters $\alpha_2, \dots, \alpha_k$ where $\alpha_k$ is the parameter corresponding to "the probability of having k groups" (selecting each $\alpha_k$ between 0 to 30 is recommended and using the other parameter <code>mult.alpha</code> to be its multiplier. The default is "default").
<code>mult.alpha</code>	the power $s$ from $n^s$ to be multiplied to the Dirichlet prior parameters <code>alpha</code> (selecting <code>mult.alpha</code> in $[0, 1)$ is recommended). The default is $\frac{1}{2}$ .

**Details**

BCVI-CSL is defined as follows.

Let

$$r_k(\mathbf{x}) = \frac{\max_j \text{CSL}(\mathbf{j}) - \text{CSL}(\mathbf{k})}{\sum_{i=2}^K (\max_j \text{CSL}(\mathbf{j}) - \text{CSL}(\mathbf{i}))}.$$

Assume that

$$f(\mathbf{x}|\mathbf{p}) = C(\mathbf{p}) \prod_{k=2}^K p_k^{nr_k(\mathbf{x})}$$

represents the conditional probability density function of the dataset given  $\mathbf{p}$ , where  $C(\mathbf{p})$  is the normalizing constant. Assume further that  $\mathbf{p}$  follows a Dirichlet prior distribution with parameters  $\boldsymbol{\alpha} = (\alpha_2, \dots, \alpha_K)$ . The posterior distribution of  $\mathbf{p}$  still remains a Dirichlet distribution with parameters  $(\alpha_2 + nr_2(\mathbf{x}), \dots, \alpha_K + nr_K(\mathbf{x}))$ .

The BCVI is then defined as

$$BCVI(k) = E[p_k|\mathbf{x}] = \frac{\alpha_k + nr_k(\mathbf{x})}{\alpha_0 + n}$$

where  $\alpha_0 = \sum_{k=2}^K \alpha_k$ .

The variance of  $p_k$  can be computed as

$$Var(p_k|\mathbf{x}) = \frac{(\alpha_k + nr_k(x))(\alpha_0 + n - \alpha_k - nr_k(x))}{(\alpha_0 + n)^2(\alpha_0 + n + 1)}.$$

### Value

BCVI	the dataframe where the first and the second columns are the number of groups k and BCVI(k), respectively, for k from 2 to kmax.
VAR	the data frame where the first and the second columns are the number of groups k and the variance of $p_k$ , respectively, for k from 2 to kmax.
CVI	the data frame where the first and the second columns are the number of groups k and the original CSL(k), respectively, for k from 2 to kmax.

### Author(s)

Nathakhun Wiroonsri and Onthada Preedasawakul

### References

- C. H. Chou, M. C. Su, E. Lai, "A new cluster validity measure and its application to image compression," *Pattern Anal Applic*, 7, 205-220 (2004).
- O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, *Computational Statistics & Data Analysis*, 202, 108053, 2025. [doi:10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

### See Also

[B2\\_data](#), [B\\_TANG.IDX](#), [B\\_WP.IDX](#), [B\\_Wvalid](#), [B\\_DB.IDX](#)

### Examples

```
library(BayesCVI)

# The data included in this package.
data = B2_data[,1:2]

# alpha
aalpha = c(5,5,5,20,20,20,0.5,0.5,0.5)

B.CSL = B_CSL.IDX(x = scale(data), kmax=10, method = "kmeans",
                 nstart = 100, alpha = aalpha, mult.alpha = 1/2)

# plot the BCVI
```



```
pplot = plot_BCVI(B.CSL)
pplot$plot_index
pplot$plot_BCVI
pplot$error_bar_plot
```

B\_DB.IDX

*BCVI-Davies-Bouldin (DB) and DB\* (DBs) indexes***Description**

Compute Bayesian cluster validity index (BCVI) from two to `kmax` groups using DB and/or DBs as the underlying cluster validity index (CVI) with the user's selected Dirichlet prior parameters. The full detail of BCVI can be found in the paper Wiroonsri and Preedasawakul (2024).

**Usage**

```
B_DB.IDX(x, kmax, method = "kmeans", indexlist = "all", p = 2, q = 2,
         nstart = 100, alpha = "default", mult.alpha = 1/2)
```

**Arguments**

<code>x</code>	a numeric data frame or matrix where each column is a variable to be used for cluster analysis and each row is a data point.
<code>kmax</code>	a maximum number of clusters to be considered.
<code>method</code>	a character string indicating which clustering method to be used ("kmeans", "hclust_complete", "hclust_average", "hclust_single"). The default is "kmeans".
<code>indexlist</code>	a character string indicating which cluster validity indexes to be computed ("all", "DB", "DBs"). More than one indexes can be selected.
<code>p</code>	the power of the Minkowski distance between centroids of clusters. The default is 2.
<code>q</code>	the power of dispersion measure of a cluster. The default is 2.
<code>nstart</code>	a maximum number of initial random sets for kmeans for method = "kmeans". The default is 100.
<code>alpha</code>	Dirichlet prior parameters $\alpha_2, \dots, \alpha_k$ where $\alpha_k$ is the parameter corresponding to "the probability of having k groups" (selecting each $\alpha_k$ between 0 to 30 is recommended and using the other parameter <code>mult.alpha</code> to be its multiplier. The default is "default".)
<code>mult.alpha</code>	the power $s$ from $n^s$ to be multiplied to the Dirichlet prior parameters <code>alpha</code> (selecting <code>mult.alpha</code> in $[0, 1)$ is recommended). The default is $\frac{1}{2}$ .

### Details

BCVI-DB is defined as follows.

Let

$$r_k(\mathbf{x}) = \frac{\max_j \text{CVI}(\mathbf{j}) - \text{CVI}(\mathbf{k})}{\sum_{i=2}^K (\max_j \text{CVI}(\mathbf{j}) - \text{CVI}(\mathbf{i}))}.$$

where CVI indicates DB or DBs index.

Assume that

$$f(\mathbf{x}|\mathbf{p}) = C(\mathbf{p}) \prod_{k=2}^K p_k^{nr_k(x)}$$

represents the conditional probability density function of the dataset given  $\mathbf{p}$ , where  $C(\mathbf{p})$  is the normalizing constant. Assume further that  $\mathbf{p}$  follows a Dirichlet prior distribution with parameters  $\alpha = (\alpha_2, \dots, \alpha_K)$ . The posterior distribution of  $\mathbf{p}$  still remains a Dirichlet distribution with parameters  $(\alpha_2 + nr_2(\mathbf{x}), \dots, \alpha_K + nr_K(\mathbf{x}))$ .

The BCVI is then defined as

$$BCVI(k) = E[p_k|\mathbf{x}] = \frac{\alpha_k + nr_k(\mathbf{x})}{\alpha_0 + n}$$

where  $\alpha_0 = \sum_{k=2}^K \alpha_k$ .

The variance of  $p_k$  can be computed as

$$Var(p_k|\mathbf{x}) = \frac{(\alpha_k + nr_k(x))(\alpha_0 + n - \alpha_k - nr_k(x))}{(\alpha_0 + n)^2(\alpha_0 + n + 1)}.$$

### Value

BCVI	the dataframe where the first and the second columns are the number of groups k and BCVI(k), respectively, for k from 2 to kmax.
VAR	the data frame where the first and the second columns are the number of groups k and the variance of $p_k$ , respectively, for k from 2 to kmax.
CVI	the data frame where the first and the second columns are the number of groups k and the original DB(k) or DBs(k), respectively, for k from 2 to kmax.

### Author(s)

Nathakhun Wiroonsri and Onthada Preedasawakul

### References

- D. L. Davies, D. W. Bouldin, "A cluster separation measure," *IEEE Trans Pattern Anal Machine Intell*, 1, 224-227 (1979).
- M. Kim, R. S. Ramakrishna, "New indices for cluster validity assessment," *Pattern Recognition Letters*, 26, 2353-2363 (2005).
- O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, *Computational Statistics & Data Analysis*, 202, 108053, 2025. doi:10.1016/j.csda.2024.108053

**See Also**

[B2\\_data](#), [B\\_TANG.IDX](#), [B\\_WP.IDX](#), [B\\_Wvalid](#), [B\\_DI.IDX](#)

**Examples**

```
library(BayesCVI)

# The data included in this package.
data = B2_data[,1:2]

# alpha
aalpha = c(5,5,5,20,20,20,0.5,0.5,0.5)

B.DB = B_DB.IDX(x = scale(data), kmax=10, method = "kmeans", indexlist = "all",
               p = 2, q = 2, nstart = 100, alpha = "default", mult.alpha = 1/2)

# plot the BCVI-DB

pplot = plot_BCVI(B.DB$DB)
pplot$plot_index
pplot$plot_BCVI
pplot$error_bar_plot

# plot the BCVI-DBs

pplot = plot_BCVI(B.DB$DBs)
pplot$plot_index
pplot$plot_BCVI
pplot$error_bar_plot
```

---

B\_DI.IDX

*BCVI-Dunn index (DI)*

---

**Description**

Compute Bayesian cluster validity index (BCVI) from two to kmax groups using Dunn index (DI) as the underlying cluster validity index (CVI) with the user's selected Dirichlet prior parameters. The full detail of BCVI can be found in the paper Wiroonsri and Preedasawakul (2024).

**Usage**

```
B_DI.IDX(x, kmax, method = "kmeans", nstart = 100, alpha = "default", mult.alpha = 1/2)
```

**Arguments**

x	a numeric data frame or matrix where each column is a variable to be used for cluster analysis and each row is a data point.
kmax	a maximum number of clusters to be considered.

method	a character string indicating which clustering method to be used ("kmeans", "hclust_complete", "hclust_average", "hclust_single"). The default is "kmeans".
nstart	a maximum number of initial random sets for kmeans for method = "kmeans". The default is 100.
alpha	Dirichlet prior parameters $\alpha_2, \dots, \alpha_k$ where $\alpha_k$ is the parameter corresponding to "the probability of having k groups" (selecting each $\alpha_k$ between 0 to 30 is recommended and using the other parameter mult.alpha to be its multiplier. The default is "default".
mult.alpha	the power $s$ from $n^s$ to be multiplied to the Dirichlet prior parameters alpha (selecting mult.alpha in $[\theta, 1)$ is recommended). The default is $\frac{1}{2}$ .

### Details

BCVI-DI is defined as follows. Let

$$r_k(\mathbf{x}) = \frac{\mathbf{DI}(\mathbf{k}) - \min_j \mathbf{DI}(\mathbf{j})}{\sum_{i=2}^K (\mathbf{DI}(\mathbf{i}) - \min_j \mathbf{DI}(\mathbf{j}))}$$

Assume that

$$f(\mathbf{x}|\mathbf{p}) = C(\mathbf{p}) \prod_{k=2}^K p_k^{nr_k(x)}$$

represents the conditional probability density function of the dataset given  $\mathbf{p}$ , where  $C(\mathbf{p})$  is the normalizing constant. Assume further that  $\mathbf{p}$  follows a Dirichlet prior distribution with parameters  $\boldsymbol{\alpha} = (\alpha_2, \dots, \alpha_K)$ . The posterior distribution of  $\mathbf{p}$  still remains a Dirichlet distribution with parameters  $(\alpha_2 + nr_2(\mathbf{x}), \dots, \alpha_K + nr_K(\mathbf{x}))$ .

The BCVI is then defined as

$$BCVI(k) = E[p_k|\mathbf{x}] = \frac{\alpha_k + nr_k(\mathbf{x})}{\alpha_0 + n}$$

where  $\alpha_0 = \sum_{k=2}^K \alpha_k$ .

The variance of  $p_k$  can be computed as

$$Var(p_k|\mathbf{x}) = \frac{(\alpha_k + nr_k(x))(\alpha_0 + n - \alpha_k - nr_k(x))}{(\alpha_0 + n)^2(\alpha_0 + n + 1)}.$$

### Value

BCVI	the dataframe where the first and the second columns are the number of groups k and $BCVI(k)$ , respectively, for k from 2 to kmax.
VAR	the data frame where the first and the second columns are the number of groups k and the variance of $p_k$ , respectively, for k from 2 to kmax.
CVI	the data frame where the first and the second columns are the number of groups k and the original $DI(k)$ , respectively, for k from 2 to kmax.

**Author(s)**

Nathakhun Wiroonsri and Onthada Preedasawakul

**References**

J. C. Dunn, "A fuzzy relative of the ISODATA process and its use in detecting compact well-separated clusters," *J Cybern*, 3(3), 32-57 (1973).

O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, *Computational Statistics & Data Analysis*, 202, 108053, 2025. [doi:10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

**See Also**

[B2\\_data](#), [B\\_TANG.IDX](#), [B\\_XB.IDX](#), [B\\_Wvalid](#), [B\\_DB.IDX](#)

**Examples**

```
library(BayesCVI)

# The data included in this package.
data = B2_data[,1:2]

# alpha
aalpaha = c(5,5,5,20,20,20,0.5,0.5,0.5)

B.DI = B_DI.IDX(x = scale(data), kmax=10, method = "kmeans",
               nstart = 100, alpha = aalpha, mult.alpha = 1/2)

# plot the BCVI

ppplot = plot_BCVI(B.DI)
ppplot$plot_index
ppplot$plot_BCVI
ppplot$error_bar_plot
```

---

B\_GC.IDX

*BCVI-The generalized C (GC) index*

---

**Description**

Compute Bayesian cluster validity index (BCVI) from two to kmax groups using all or part of GC1 GC2 GC3 and GC4 as the underling cluster validity index (CVI) with the user's selected Dirichlet prior parameters. The full detail of BCVI can be found in the paper Wiroonsri and Preedasawakul (2024).

**Usage**

```
B_GC.IDX(x, kmax, indexlist = "all", method = "FCM", fzm = 2, iter = 100,
         nstart = 20, alpha = "default", mult.alpha = 1/2)
```

**Arguments**

x	a numeric data frame or matrix where each column is a variable to be used for cluster analysis and each row is a data point.
kmax	a maximum number of clusters to be considered.
indexlist	a character string indicating which The generalized C index be computed ("a11","GC1","GC2","GC3","GC4"). More than one indexes can be selected.
method	a character string indicating which clustering method to be used ("FCM" or "EM"). The default is "FCM".
fzm	a number greater than 1 giving the degree of fuzzification for method = "FCM". The default is 2.
iter	a maximum number of iterations for method = "FCM". The default is 100.
nstart	a maximum number of initial random sets for FCM for method = "FCM". The default is 20.
alpha	Dirichlet prior parameters $\alpha_2, \dots, \alpha_k$ where $\alpha_k$ is the parameter corresponding to "the probability of having k groups" (selecting each $\alpha_k$ between 0 to 30 is recommended and using the other parameter mult.alpha to be its multiplier. The default is "default".)
mult.alpha	the power $s$ from $n^s$ to be multiplied to the Dirichlet prior parameters alpha (selecting mult.alpha in $[0, 1)$ is recommended). The default is $\frac{1}{2}$ .

**Details**

BCVI-GC is defined as follows.

Let

$$r_k(\mathbf{x}) = \frac{\max_j \text{CVI}(j) - \text{CVI}(k)}{\sum_{i=2}^K (\max_j \text{CVI}(j) - \text{CVI}(i))}.$$

where CVI is one of the GC1 GC2 GC3 or GC4 index.

Assume that

$$f(\mathbf{x}|\mathbf{p}) = C(\mathbf{p}) \prod_{k=2}^K p_k^{nr_k(x)}$$

represents the conditional probability density function of the dataset given  $\mathbf{p}$ , where  $C(\mathbf{p})$  is the normalizing constant. Assume further that  $\mathbf{p}$  follows a Dirichlet prior distribution with parameters  $\boldsymbol{\alpha} = (\alpha_2, \dots, \alpha_K)$ . The posterior distribution of  $\mathbf{p}$  still remains a Dirichlet distribution with parameters  $(\alpha_2 + nr_2(\mathbf{x}), \dots, \alpha_K + nr_K(\mathbf{x}))$ .

The BCVI is then defined as

$$BCVI(k) = E[p_k|\mathbf{x}] = \frac{\alpha_k + nr_k(\mathbf{x})}{\alpha_0 + n}$$

where  $\alpha_0 = \sum_{k=2}^K \alpha_k$ .

The variance of  $p_k$  can be computed as

$$\text{Var}(p_k|\mathbf{x}) = \frac{(\alpha_k + nr_k(x))(\alpha_0 + n - \alpha_k - nr_k(x))}{(\alpha_0 + n)^2(\alpha_0 + n + 1)}.$$

### Value

BCVI	the dataframe where the first and the second columns are the number of groups $k$ and $\text{BCVI}(k)$ , respectively, for $k$ from 2 to $k_{\max}$ .
VAR	the data frame where the first and the second columns are the number of groups $k$ and the variance of $p_k$ , respectively, for $k$ from 2 to $k_{\max}$ .
CVI	the data frame where the first and the second columns are the number of groups $k$ and the original $\text{GC1}(k)$ $\text{GC2}(k)$ $\text{GC3}(k)$ $\text{GC4}(k)$ , respectively, for $k$ from 2 to $k_{\max}$ .

### Author(s)

Nathakhun Wiroonsri and Onthada Preedasawakul

### References

- J. C. Bezdek, M. Moshtaghi, T. Runkler, and C. Leckie, "The generalized  $c$  index for internal fuzzy cluster validity," *IEEE Transactions on Fuzzy Systems*, vol. 24, no. 6, pp. 1500–1512, 2016. <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7429723&isnumber=7797168>
- O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, *Computational Statistics & Data Analysis*, 202, 108053, 2025. [doi:10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

### See Also

[B7\\_data](#), [B\\_TANG.IDX](#), [B\\_XB.IDX](#), [B\\_Wvalid](#), [B\\_DB.IDX](#)

### Examples

```
library(BayesCVI)

# The data included in this package.
data = B7_data[,1:2]

# alpha
aalpha = c(5,5,5,20,20,20,0.5,0.5,0.5)

B.GC = B_GC.IDX(x = scale(data), kmax = 10, indexlist = "GC1",
               method = "FCM", fzm = 2, iter = 100,
               nstart = 20, alpha = aalpha, mult.alpha = 1/2)

# plot the BCVI-GC1

pplot = plot_BCVI(B.GC$GC1)
pplot$plot_index
pplot$plot_BCVI
```

pplot\$error\_bar\_plot

---

B\_HF.IDX

*BCVI-HF index*

---

### Description

Compute Bayesian cluster validity index (BCVI) from two to `kmax` groups using HF as the underlying cluster validity index (CVI) with the user's selected Dirichlet prior parameters. The full detail of BCVI can be found in the paper Wiroonsri and Preedasawakul (2024).

### Usage

```
B_HF.IDX(x, kmax, method = "FCM", fzm = 2, nstart = 20,
         iter = 100, alpha = "default", mult.alpha = 1/2)
```

### Arguments

<code>x</code>	a numeric data frame or matrix where each column is a variable to be used for cluster analysis and each row is a data point.
<code>kmax</code>	a maximum number of clusters to be considered.
<code>method</code>	a character string indicating which clustering method to be used ("FCM" or "EM"). The default is "FCM".
<code>fzm</code>	a number greater than 1 giving the degree of fuzzification for method = "FCM". The default is 2.
<code>nstart</code>	a maximum number of initial random sets for FCM for method = "FCM". The default is 20.
<code>iter</code>	a maximum number of iterations for method = "FCM". The default is 100.
<code>alpha</code>	Dirichlet prior parameters $\alpha_2, \dots, \alpha_k$ where $\alpha_k$ is the parameter corresponding to "the probability of having k groups" (selecting each $\alpha_k$ between 0 to 30 is recommended and using the other parameter <code>mult.alpha</code> to be its multiplier. The default is "default".)
<code>mult.alpha</code>	the power $s$ from $n^s$ to be multiplied to the Dirichlet prior parameters <code>alpha</code> (selecting <code>mult.alpha</code> in $[0, 1)$ is recommended). The default is $\frac{1}{2}$ .

### Details

BCVI-HF is defined as follows.

Let

$$r_k(\mathbf{x}) = \frac{\max_j \mathbf{HF}(\mathbf{j}) - \mathbf{HF}(\mathbf{k})}{\sum_{i=2}^{\mathbf{K}} (\max_j \mathbf{HF}(\mathbf{j}) - \mathbf{HF}(\mathbf{i}))}$$



Assume that

$$f(\mathbf{x}|\mathbf{p}) = C(\mathbf{p}) \prod_{k=2}^K p_k^{nr_k(x)}$$

represents the conditional probability density function of the dataset given  $\mathbf{p}$ , where  $C(\mathbf{p})$  is the normalizing constant. Assume further that  $\mathbf{p}$  follows a Dirichlet prior distribution with parameters  $\boldsymbol{\alpha} = (\alpha_2, \dots, \alpha_K)$ . The posterior distribution of  $\mathbf{p}$  still remains a Dirichlet distribution with parameters  $(\alpha_2 + nr_2(\mathbf{x}), \dots, \alpha_K + nr_K(\mathbf{x}))$ .

The BCVI is then defined as

$$BCVI(k) = E[p_k|\mathbf{x}] = \frac{\alpha_k + nr_k(\mathbf{x})}{\alpha_0 + n}$$

where  $\alpha_0 = \sum_{k=2}^K \alpha_k$ .

The variance of  $p_k$  can be computed as

$$Var(p_k|\mathbf{x}) = \frac{(\alpha_k + nr_k(x))(\alpha_0 + n - \alpha_k - nr_k(x))}{(\alpha_0 + n)^2(\alpha_0 + n + 1)}.$$

### Value

BCVI	the dataframe where the first and the second columns are the number of groups $k$ and $BCVI(k)$ , respectively, for $k$ from 2 to $kmax$ .
VAR	the data frame where the first and the second columns are the number of groups $k$ and the variance of $p_k$ , respectively, for $k$ from 2 to $kmax$ .
CVI	the data frame where the first and the second columns are the number of groups $k$ and the original $HF(k)$ , respectively, for $k$ from 2 to $kmax$ .

### Author(s)

Nathakhun Wiroonsri and Onthada Preedasawakul

### References

F. Haouas, Z. Ben Dhiaf, A. Hammouda and B. Solaiman, "A new efficient fuzzy cluster validity index: Application to images clustering," 2017 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE), Naples, Italy, 2017, pp. 1-6. <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8015651&isnumber=8015374>

O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, Computational Statistics & Data Analysis, 202, 108053, 2025. [doi:10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

### See Also

[B7\\_data](#), [B\\_TANG.IDX](#), [B\\_WP.IDX](#), [B\\_Wvalid](#), [B\\_DB.IDX](#)

**Examples**

```

library(BayesCVI)

# The data included in this package.
data = B7_data[,1:2]

# alpha
aalpha = c(5,5,5,20,20,20,0.5,0.5,0.5)

B.HF = B_HF.IDX(x = scale(data), kmax =10, method = "FCM", fzm = 2,
               nstart = 20, iter = 100, alpha = aalpha, mult.alpha = 1/2)

# plot the BCVI

pplot = plot_BCVI(B.HF)
pplot$plot_index
pplot$plot_BCVI
pplot$error_bar_plot

```

B\_KPBM.IDX

*BCVI-Modified Kernel form of Pakhira-Bandyopadhyay-Maulik (KPBM) index*

**Description**

Compute Bayesian cluster validity index (BCVI) from two to kmax groups using Modified Kernel form of Pakhira-Bandyopadhyay-Maulik (KPBM) as the underlying cluster validity index (CVI) with the user's selected Dirichlet prior parameters. The full detail of BCVI can be found in the paper Wiroonsri and Preedasawakul (2024).

**Usage**

```

B_KPBM.IDX(x, kmax, method = "FCM", fzm = 2, nstart = 20,
           iter = 100, alpha = "default", mult.alpha = 1/2)

```

**Arguments**

x	a numeric data frame or matrix where each column is a variable to be used for cluster analysis and each row is a data point.
kmax	a maximum number of clusters to be considered.
method	a character string indicating which clustering method to be used ("FCM" or "EM"). The default is "FCM".
fzm	a number greater than 1 giving the degree of fuzzification for method = "FCM". The default is 2.
nstart	a maximum number of initial random sets for FCM for method = "FCM". The default is 20.
iter	a maximum number of iterations for method = "FCM". The default is 100.

alpha	Dirichlet prior parameters $\alpha_2, \dots, \alpha_k$ where $\alpha_k$ is the parameter corresponding to "the probability of having k groups" (selecting each $\alpha_k$ between 0 to 30 is recommended and using the other parameter <code>mult.alpha</code> to be its multiplier. The default is "default").
mult.alpha	the power $s$ from $n^s$ to be multiplied to the Dirichlet prior parameters alpha (selecting <code>mult.alpha</code> in $[\theta, 1)$ is recommended). The default is $\frac{1}{2}$ .

### Details

BCVI-KPBM is defined as follows. Let

$$r_k(\mathbf{x}) = \frac{\mathbf{KPBM}(k) - \min_j \mathbf{KPBM}(j)}{\sum_{i=2}^K (\mathbf{KPBM}(i) - \min_j \mathbf{KPBM}(j))}$$

Assume that

$$f(\mathbf{x}|\mathbf{p}) = C(\mathbf{p}) \prod_{k=2}^K p_k^{nr_k(x)}$$

represents the conditional probability density function of the dataset given  $\mathbf{p}$ , where  $C(\mathbf{p})$  is the normalizing constant. Assume further that  $\mathbf{p}$  follows a Dirichlet prior distribution with parameters  $\boldsymbol{\alpha} = (\alpha_2, \dots, \alpha_K)$ . The posterior distribution of  $\mathbf{p}$  still remains a Dirichlet distribution with parameters  $(\alpha_2 + nr_2(\mathbf{x}), \dots, \alpha_K + nr_K(\mathbf{x}))$ .

The BCVI is then defined as

$$BCVI(k) = E[p_k|\mathbf{x}] = \frac{\alpha_k + nr_k(\mathbf{x})}{\alpha_0 + n}$$

where  $\alpha_0 = \sum_{k=2}^K \alpha_k$ .

The variance of  $p_k$  can be computed as

$$Var(p_k|\mathbf{x}) = \frac{(\alpha_k + nr_k(x))(\alpha_0 + n - \alpha_k - nr_k(x))}{(\alpha_0 + n)^2(\alpha_0 + n + 1)}.$$

### Value

BCVI	the dataframe where the first and the second columns are the number of groups k and $BCVI(k)$ , respectively, for k from 2 to <code>kmax</code> .
VAR	the data frame where the first and the second columns are the number of groups k and the variance of $p_k$ , respectively, for k from 2 to <code>kmax</code> .
CVI	the data frame where the first and the second columns are the number of groups k and the original $\mathbf{KPBM}(k)$ , respectively, for k from 2 to <code>kmax</code> .

### Author(s)

Nathakhun Wiroonsri and Onthada Preedasawakul

## References

- C. Alok. (2010). "An investigation of clustering algorithms and soft computing approaches for pattern recognition," Department of Computer Science, Assam University. <http://hdl.handle.net/10603/93443>
- O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, Computational Statistics & Data Analysis, 202, 108053, 2025. [doi:10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

## See Also

[B7\\_data](#), [B\\_TANG.IDX](#), [B\\_WP.IDX](#), [B\\_Wvalid](#), [B\\_DB.IDX](#)

## Examples

```
library(BayesCVI)

# The data included in this package.
data = B7_data[,1:2]

# alpha
aalpha = c(5,5,5,20,20,20,0.5,0.5,0.5)

B.KPBM = B_KPBM.IDX(x = scale(data), kmax =10, method = "FCM", fzm = 2, nstart = 20,
                    iter = 100, alpha = aalpha, mult.alpha = 1/2)

# plot the BCVI

pplot = plot_BCVI(B.KPBM)
pplot$plot_index
pplot$plot_BCVI
pplot$error_bar_plot
```

---

B\_KWON.IDX

*BCVI-KWON index*

---

## Description

Compute Bayesian cluster validity index (BCVI) from two to kmax groups using KWON as the underlying cluster validity index (CVI) with the user's selected Dirichlet prior parameters. The full detail of BCVI can be found in the paper Wiroonsri and Preedasawakul (2024).

## Usage

```
B_KWON.IDX(x, kmax, method = "FCM", fzm = 2, nstart = 20,
            iter = 100, alpha = "default", mult.alpha = 1/2)
```

**Arguments**

x	a numeric data frame or matrix where each column is a variable to be used for cluster analysis and each row is a data point.
kmax	a maximum number of clusters to be considered.
method	a character string indicating which clustering method to be used ("FCM" or "EM"). The default is "FCM".
fzm	a number greater than 1 giving the degree of fuzzification for method = "FCM". The default is 2.
nstart	a maximum number of initial random sets for FCM for method = "FCM". The default is 20.
iter	a maximum number of iterations for method = "FCM". The default is 100.
alpha	Dirichlet prior parameters $\alpha_2, \dots, \alpha_k$ where $\alpha_k$ is the parameter corresponding to "the probability of having k groups" (selecting each $\alpha_k$ between 0 to 30 is recommended and using the other parameter <code>mult.alpha</code> to be its multiplier. The default is "default".)
mult.alpha	the power $s$ from $n^s$ to be multiplied to the Dirichlet prior parameters <code>alpha</code> (selecting <code>mult.alpha</code> in $[0, 1)$ is recommended). The default is $\frac{1}{2}$ .

**Details**

BCVI-KWON is defined as follows.

Let

$$r_k(\mathbf{x}) = \frac{\max_j \mathbf{KWON}(j) - \mathbf{KWON}(k)}{\sum_{i=2}^K (\max_j \mathbf{KWON}(j) - \mathbf{KWON}(i))}.$$

Assume that

$$f(\mathbf{x}|\mathbf{p}) = C(\mathbf{p}) \prod_{k=2}^K p_k^{nr_k(x)}$$

represents the conditional probability density function of the dataset given  $\mathbf{p}$ , where  $C(\mathbf{p})$  is the normalizing constant. Assume further that  $\mathbf{p}$  follows a Dirichlet prior distribution with parameters  $\boldsymbol{\alpha} = (\alpha_2, \dots, \alpha_K)$ . The posterior distribution of  $\mathbf{p}$  still remains a Dirichlet distribution with parameters  $(\alpha_2 + nr_2(\mathbf{x}), \dots, \alpha_K + nr_K(\mathbf{x}))$ .

The BCVI is then defined as

$$BCVI(k) = E[p_k|\mathbf{x}] = \frac{\alpha_k + nr_k(\mathbf{x})}{\alpha_0 + n}$$

where  $\alpha_0 = \sum_{k=2}^K \alpha_k$ .

The variance of  $p_k$  can be computed as

$$Var(p_k|\mathbf{x}) = \frac{(\alpha_k + nr_k(x))(\alpha_0 + n - \alpha_k - nr_k(x))}{(\alpha_0 + n)^2(\alpha_0 + n + 1)}.$$

**Value**

BCVI	the dataframe where the first and the second columns are the number of groups $k$ and $BCVI(k)$ , respectively, for $k$ from 2 to $k_{max}$ .
VAR	the data frame where the first and the second columns are the number of groups $k$ and the variance of $p_k$ , respectively, for $k$ from 2 to $k_{max}$ .
CVI	the data frame where the first and the second columns are the number of groups $k$ and the original $KWON(k)$ , respectively, for $k$ from 2 to $k_{max}$ .

**Author(s)**

Nathakhun Wiroonsri and Onthada Preedasawakul

**References**

- S. H. Kwon, "Cluster validity index for fuzzy clustering," *Electronics letters*, vol. 34, no. 22, pp. 2176–2177, 1998. doi:[10.1049/el:19981523](https://doi.org/10.1049/el:19981523)
- O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, *Computational Statistics & Data Analysis*, 202, 108053, 2025. doi:[10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

**See Also**

[B7\\_data](#), [B\\_TANG.IDX](#), [B\\_WP.IDX](#), [B\\_Wvalid](#), [B\\_DB.IDX](#)

**Examples**

```
library(BayesCVI)

# The data included in this package.
data = B7_data[,1:2]

# alpha
aalpna = c(5,5,5,20,20,20,0.5,0.5,0.5)

B.KWON = B_KWON.IDX(x = scale(data), kmax =10, method = "FCM", fzm = 2, nstart = 20,
                    iter = 100, alpha = aalpha, mult.alpha = 1/2)

# plot the BCVI

pplot = plot_BCVI(B.KWON)
pplot$plot_index
pplot$plot_BCVI
pplot$error_bar_plot
```

### Description

Compute Bayesian cluster validity index (BCVI) from two to kmax groups using KWON2 as the underlying cluster validity index (CVI) with the user's selected Dirichlet prior parameters. The full detail of BCVI can be found in the paper Wiroonsri and Preedasawakul (2024).

### Usage

```
B_KWON2.IDX(x, kmax, method = "FCM", fzm = 2, nstart = 20,
            iter = 100, alpha = "default", mult.alpha = 1/2)
```

### Arguments

x	a numeric data frame or matrix where each column is a variable to be used for cluster analysis and each row is a data point.
kmax	a maximum number of clusters to be considered.
method	a character string indicating which clustering method to be used ("FCM" or "EM"). The default is "FCM".
fzm	a number greater than 1 giving the degree of fuzzification for method = "FCM". The default is 2.
nstart	a maximum number of initial random sets for FCM for method = "FCM". The default is 20.
iter	a maximum number of iterations for method = "FCM". The default is 100.
alpha	Dirichlet prior parameters $\alpha_2, \dots, \alpha_k$ where $\alpha_k$ is the parameter corresponding to "the probability of having k groups" (selecting each $\alpha_k$ between 0 to 30 is recommended and using the other parameter mult.alpha to be its multiplier. The default is "default".)
mult.alpha	the power $s$ from $n^s$ to be multiplied to the Dirichlet prior parameters alpha (selecting mult.alpha in $[0, 1)$ is recommended). The default is $\frac{1}{2}$ .

### Details

BCVI-KWON2 is defined as follows.

Let

$$r_k(\mathbf{x}) = \frac{\max_j \mathbf{KWON2}(j) - \mathbf{KWON2}(k)}{\sum_{i=2}^K (\max_j \mathbf{KWON2}(j) - \mathbf{KWON2}(i))}$$

Assume that

$$f(\mathbf{x}|\mathbf{p}) = C(\mathbf{p}) \prod_{k=2}^K p_k^{nr_k(x)}$$

represents the conditional probability density function of the dataset given  $\mathbf{p}$ , where  $C(\mathbf{p})$  is the normalizing constant. Assume further that  $\mathbf{p}$  follows a Dirichlet prior distribution with parameters  $\boldsymbol{\alpha} = (\alpha_2, \dots, \alpha_K)$ . The posterior distribution of  $\mathbf{p}$  still remains a Dirichlet distribution with parameters  $(\alpha_2 + nr_2(\mathbf{x}), \dots, \alpha_K + nr_K(\mathbf{x}))$ .

The BCVI is then defined as

$$BCVI(k) = E[p_k | \mathbf{x}] = \frac{\alpha_k + nr_k(\mathbf{x})}{\alpha_0 + n}$$

where  $\alpha_0 = \sum_{k=2}^K \alpha_k$ .

The variance of  $p_k$  can be computed as

$$Var(p_k | \mathbf{x}) = \frac{(\alpha_k + nr_k(x))(\alpha_0 + n - \alpha_k - nr_k(x))}{(\alpha_0 + n)^2(\alpha_0 + n + 1)}.$$

### Value

BCVI	the dataframe where the first and the second columns are the number of groups $k$ and $BCVI(k)$ , respectively, for $k$ from 2 to $kmax$ .
VAR	the data frame where the first and the second columns are the number of groups $k$ and the variance of $p_k$ , respectively, for $k$ from 2 to $kmax$ .
CVI	the data frame where the first and the second columns are the number of groups $k$ and the original $KWON2(k)$ , respectively, for $k$ from 2 to $kmax$ .

### Author(s)

Nathakhun Wiroonsri and Onthada Preedasawakul

### References

- S. H. Kwon, J. Kim, and S. H. Son, "Improved cluster validity index for fuzzy clustering," *Electronics Letters*, vol. 57, no. 21, pp. 792–794, 2021.
- O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, *Computational Statistics & Data Analysis*, 202, 108053, 2025. [doi:10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

### See Also

[B7\\_data](#), [B\\_TANG.IDX](#), [B\\_WP.IDX](#), [B\\_Wvalid](#), [B\\_DB.IDX](#)

### Examples

```
library(BayesCVI)

# The data included in this package.
data = B7_data[,1:2]

# alpha
aalpha = c(5,5,5,20,20,20,0.5,0.5,0.5)
```



```

B.KWON2 = B_KWON2.IDX(x = scale(data), kmax =10, method = "FCM", fzm = 2,
                      nstart = 20, iter = 100, alpha = aalpha, mult.alpha = 1/2)

# plot the BCVI

pplot = plot_BCVI(B.KWON2)
pplot$plot_index
pplot$plot_BCVI
pplot$error_bar_plot

```

B\_PB.IDX

*BCVI-Point biserial correlation (PB)***Description**

Compute Bayesian cluster validity index (BCVI) from two to kmax groups using Point biserial correlation (PB) as the underlying cluster validity index (CVI) with the user's selected Dirichlet prior parameters. The full detail of BCVI can be found in the paper Wiroonsri and Preedasawakul (2024).

**Usage**

```

B_PB.IDX(x, kmax, method = "kmeans", corr = "pearson", nstart = 100,
         alpha = "default", mult.alpha = 1/2)

```

**Arguments**

x	a numeric data frame or matrix where each column is a variable to be used for cluster analysis and each row is a data point.
kmax	a maximum number of clusters to be considered.
method	a character string indicating which clustering method to be used ("kmeans", "hclust_complete", "hclust_average", "hclust_single"). The default is "kmeans".
corr	a character string indicating which correlation coefficient is to be computed ("pearson", "kendall" or "spearman"). The default is "pearson".
nstart	a maximum number of initial random sets for kmeans for method = "kmeans". The default is 100.
alpha	Dirichlet prior parameters $\alpha_2, \dots, \alpha_k$ where $\alpha_k$ is the parameter corresponding to "the probability of having k groups" (selecting each $\alpha_k$ between 0 to 30 is recommended and using the other parameter mult.alpha to be its multiplier. The default is "default".)
mult.alpha	the power $s$ from $n^s$ to be multiplied to the Dirichlet prior parameters alpha (selecting mult.alpha in $[0, 1)$ is recommended). The default is $\frac{1}{2}$ .

### Details

BCVI-PB is defined as follows. Let

$$r_k(\mathbf{x}) = \frac{\mathbf{PB}(k) - \min_j \mathbf{PB}(j)}{\sum_{i=2}^K (\mathbf{PB}(i) - \min_j \mathbf{PB}(j))}$$

Assume that

$$f(\mathbf{x}|\mathbf{p}) = C(\mathbf{p}) \prod_{k=2}^K p_k^{nr_k(x)}$$

represents the conditional probability density function of the dataset given  $\mathbf{p}$ , where  $C(\mathbf{p})$  is the normalizing constant. Assume further that  $\mathbf{p}$  follows a Dirichlet prior distribution with parameters  $\alpha = (\alpha_2, \dots, \alpha_K)$ . The posterior distribution of  $\mathbf{p}$  still remains a Dirichlet distribution with parameters  $(\alpha_2 + nr_2(\mathbf{x}), \dots, \alpha_K + nr_K(\mathbf{x}))$ .

The BCVI is then defined as

$$BCVI(k) = E[p_k|\mathbf{x}] = \frac{\alpha_k + nr_k(\mathbf{x})}{\alpha_0 + n}$$

where  $\alpha_0 = \sum_{k=2}^K \alpha_k$ .

The variance of  $p_k$  can be computed as

$$Var(p_k|\mathbf{x}) = \frac{(\alpha_k + nr_k(x))(\alpha_0 + n - \alpha_k - nr_k(x))}{(\alpha_0 + n)^2(\alpha_0 + n + 1)}.$$

### Value

BCVI	the dataframe where the first and the second columns are the number of groups $k$ and $BCVI(k)$ , respectively, for $k$ from 2 to $kmax$ .
VAR	the data frame where the first and the second columns are the number of groups $k$ and the variance of $p_k$ , respectively, for $k$ from 2 to $kmax$ .
CVI	the data frame where the first and the second columns are the number of groups $k$ and the original $PB(k)$ , respectively, for $k$ from 2 to $kmax$ .

### Author(s)

Nathakhun Wiroonsri and Onthada Preedasawakul

### References

G. W. Miligan, "An examination of the effect of six types of error perturbation on fifteen clustering algorithms," *Psychometrika*, 45, 325-342 (1980).

O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, *Computational Statistics & Data Analysis*, 202, 108053, 2025. [doi:10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

### See Also

[B2\\_data](#), [B\\_TANG.IDX](#), [B\\_WP.IDX](#), [B\\_Wvalid](#), [B\\_DB.IDX](#)

**Examples**

```

library(BayesCVI)

# The data included in this package.
data = B2_data[,1:2]

# alpha
aalpha = c(5,5,5,20,20,20,0.5,0.5,0.5)

B.PB = B_PB.IDX(x = scale(data), kmax=10, method = "kmeans", corr = "pearson", nstart = 100,
               alpha = aalpha, mult.alpha = 1/2)

# plot the BCVI

pplot = plot_BCVI(B.PB)
pplot$plot_index
pplot$plot_BCVI
pplot$error_bar_plot

```

B\_PBM.IDX

*BCVI-Pakhira-Bandyopadhyay-Maulik (PBM) index***Description**

Compute Bayesian cluster validity index (BCVI) from two to  $k_{\max}$  groups using Pakhira-Bandyopadhyay-Maulik (PBM) as the underlying cluster validity index (CVI) with the user's selected Dirichlet prior parameters. The full detail of BCVI can be found in the paper Wiroonsri and Preedasawakul (2024).

**Usage**

```

B_PBM.IDX(x, kmax, method = "FCM", fzm = 2, nstart = 20,
          iter = 100, alpha = "default", mult.alpha = 1/2)

```

**Arguments**

<code>x</code>	a numeric data frame or matrix where each column is a variable to be used for cluster analysis and each row is a data point.
<code>kmax</code>	a maximum number of clusters to be considered.
<code>method</code>	a character string indicating which clustering method to be used ("FCM" or "EM"). The default is "FCM".
<code>fzm</code>	a number greater than 1 giving the degree of fuzzification for method = "FCM". The default is 2.
<code>nstart</code>	a maximum number of initial random sets for FCM for method = "FCM". The default is 20.
<code>iter</code>	a maximum number of iterations for method = "FCM". The default is 100.

alpha	Dirichlet prior parameters $\alpha_2, \dots, \alpha_k$ where $\alpha_k$ is the parameter corresponding to "the probability of having k groups" (selecting each $\alpha_k$ between 0 to 30 is recommended and using the other parameter <code>mult.alpha</code> to be its multiplier. The default is "default").
mult.alpha	the power $s$ from $n^s$ to be multiplied to the Dirichlet prior parameters alpha (selecting <code>mult.alpha</code> in $[\theta, 1)$ is recommended). The default is $\frac{1}{2}$ .

### Details

BCVI-PBM is defined as follows. Let

$$r_k(\mathbf{x}) = \frac{\mathbf{PBM}(k) - \min_j \mathbf{PBM}(j)}{\sum_{i=2}^K (\mathbf{PBM}(i) - \min_j \mathbf{PBM}(j))}$$

Assume that

$$f(\mathbf{x}|\mathbf{p}) = C(\mathbf{p}) \prod_{k=2}^K p_k^{nr_k(x)}$$

represents the conditional probability density function of the dataset given  $\mathbf{p}$ , where  $C(\mathbf{p})$  is the normalizing constant. Assume further that  $\mathbf{p}$  follows a Dirichlet prior distribution with parameters  $\boldsymbol{\alpha} = (\alpha_2, \dots, \alpha_K)$ . The posterior distribution of  $\mathbf{p}$  still remains a Dirichlet distribution with parameters  $(\alpha_2 + nr_2(\mathbf{x}), \dots, \alpha_K + nr_K(\mathbf{x}))$ .

The BCVI is then defined as

$$BCVI(k) = E[p_k|\mathbf{x}] = \frac{\alpha_k + nr_k(\mathbf{x})}{\alpha_0 + n}$$

where  $\alpha_0 = \sum_{k=2}^K \alpha_k$ .

The variance of  $p_k$  can be computed as

$$Var(p_k|\mathbf{x}) = \frac{(\alpha_k + nr_k(x))(\alpha_0 + n - \alpha_k - nr_k(x))}{(\alpha_0 + n)^2(\alpha_0 + n + 1)}.$$

### Value

BCVI	the dataframe where the first and the second columns are the number of groups k and $BCVI(k)$ , respectively, for k from 2 to <code>kmax</code> .
VAR	the data frame where the first and the second columns are the number of groups k and the variance of $p_k$ , respectively, for k from 2 to <code>kmax</code> .
CVI	the data frame where the first and the second columns are the number of groups k and the original $\mathbf{PBM}(k)$ , respectively, for k from 2 to <code>kmax</code> .

### Author(s)

Nathakhun Wiroonsri and Onthada Preedasawakul

## References

M. K. Pakhira, S. Bandyopadhyay, and U. Maulik, "Validity index for crisp and fuzzy clusters," *Pattern recognition*, vol. 37, no. 3, pp. 487–501, 2004.

O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, *Computational Statistics & Data Analysis*, 202, 108053, 2025. [doi:10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

## See Also

[B7\\_data](#), [B\\_TANG.IDX](#), [B\\_WP.IDX](#), [B\\_Wvalid](#), [B\\_DB.IDX](#)

## Examples

```
library(BayesCVI)

# The data included in this package.
data = B7_data[,1:2]

# alpha
aalpha = c(5,5,5,20,20,20,0.5,0.5,0.5)

B.PBM = B_PBM.IDX(x = scale(data), kmax =10, method = "FCM", fzm = 2, nstart = 20,
                  iter = 100, alpha = aalpha, mult.alpha = 1/2)

# plot the BCVI

pplot = plot_BCVI(B.PBM)
pplot$plot_index
pplot$plot_BCVI
pplot$error_bar_plot
```

---

B\_SF.IDX

*BCVI-The score function*

---

## Description

Compute Bayesian cluster validity index (BCVI) from two to  $k_{\max}$  groups using the score function (SF) as the underlying cluster validity index (CVI) with the user's selected Dirichlet prior parameters. The full detail of BCVI can be found in the paper Wiroonsri and Preedasawakul (2024).

## Usage

```
B_SF.IDX(x, kmax, method = "kmeans", nstart = 100, alpha = "default", mult.alpha = 1/2)
```

**Arguments**

x	a numeric data frame or matrix where each column is a variable to be used for cluster analysis and each row is a data point.
kmax	a maximum number of clusters to be considered.
method	a character string indicating which clustering method to be used ("kmeans", "hclust_complete", "hclust_average", "hclust_single"). The default is "kmeans".
nstart	a maximum number of initial random sets for kmeans for method = "kmeans". The default is 100.
alpha	Dirichlet prior parameters $\alpha_2, \dots, \alpha_k$ where $\alpha_k$ is the parameter corresponding to "the probability of having k groups" (selecting each $\alpha_k$ between 0 to 30 is recommended and using the other parameter mult.alpha to be its multiplier. The default is "default".
mult.alpha	the power $s$ from $n^s$ to be multiplied to the Dirichlet prior parameters alpha (selecting mult.alpha in $[\emptyset, 1)$ is recommended). The default is $\frac{1}{2}$ .

**Details**

BCVI-SF is defined as follows.

Let

$$r_k(\mathbf{x}) = \frac{\max_j \mathbf{SF}(\mathbf{j}) - \mathbf{SF}(\mathbf{k})}{\sum_{i=2}^K (\max_j \mathbf{SF}(\mathbf{j}) - \mathbf{SF}(\mathbf{i}))}.$$

Assume that

$$f(\mathbf{x}|\mathbf{p}) = C(\mathbf{p}) \prod_{k=2}^K p_k^{nr_k(x)}$$

represents the conditional probability density function of the dataset given  $\mathbf{p}$ , where  $C(\mathbf{p})$  is the normalizing constant. Assume further that  $\mathbf{p}$  follows a Dirichlet prior distribution with parameters  $\boldsymbol{\alpha} = (\alpha_2, \dots, \alpha_K)$ . The posterior distribution of  $\mathbf{p}$  still remains a Dirichlet distribution with parameters  $(\alpha_2 + nr_2(\mathbf{x}), \dots, \alpha_K + nr_K(\mathbf{x}))$ .

The BCVI is then defined as

$$BCVI(k) = E[p_k|\mathbf{x}] = \frac{\alpha_k + nr_k(\mathbf{x})}{\alpha_0 + n}$$

where  $\alpha_0 = \sum_{k=2}^K \alpha_k$ .

The variance of  $p_k$  can be computed as

$$Var(p_k|\mathbf{x}) = \frac{(\alpha_k + nr_k(x))(\alpha_0 + n - \alpha_k - nr_k(x))}{(\alpha_0 + n)^2(\alpha_0 + n + 1)}.$$

**Value**

BCVI	the dataframe where the first and the second columns are the number of groups $k$ and $BCVI(k)$ , respectively, for $k$ from 2 to $k_{max}$ .
VAR	the data frame where the first and the second columns are the number of groups $k$ and the variance of $p_k$ , respectively, for $k$ from 2 to $k_{max}$ .
CVI	the data frame where the first and the second columns are the number of groups $k$ and the original $SF(k)$ , respectively, for $k$ from 2 to $k_{max}$ .

**Author(s)**

Nathakhun Wiroonsri and Onthada Preedasawakul

**References**

S. Saitta, B. Raphael, I. Smith, "A bounded index for cluster validity," *In Perner, P.: Machine Learning and Data Mining in Pattern Recognition, Lecture Notes in Computer Science*, 4571, Springer (2007).

O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, *Computational Statistics & Data Analysis*, 202, 108053, 2025. [doi:10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

**See Also**

[B2\\_data](#), [B\\_TANG.IDX](#), [B\\_WP.IDX](#), [B\\_Wvalid](#), [B\\_DB.IDX](#)

**Examples**

```
library(BayesCVI)

# The data included in this package.
data = B2_data[,1:2]

# alpha
aalpha = c(5,5,5,20,20,20,0.5,0.5,0.5)

B.SF = B_SF.IDX(x = scale(data), kmax=10, method = "kmeans",
               nstart = 100, alpha = aalpha, mult.alpha = 1/2)

# plot the BCVI

pplot = plot_BCVI(B.SF)
pplot$plot_index
pplot$plot_BCVI
pplot$error_bar_plot
```

---

B_STRPBM.IDX	<i>BCVI-Starczewski and Pakhira-Bandyopadhyay-Maulik for crisp clustering indexes</i>
--------------	---

---

### Description

Compute Bayesian cluster validity index (BCVI) from two to kmax groups using Starczewski (STR) and/or Pakhira-Bandyopadhyay-Maulik (PBM) as the underlying cluster validity index (CVI) and Dirichlet prior parameters of the user's choice. The full detail of BCVI can be found in the paper Wiroonsri and Preedasawakul (2024).

### Usage

```
B_STRPBM.IDX(x, kmax, method = "kmeans", indexlist = "all",
             nstart = 100, alpha = "default", mult.alpha = 1/2)
```

### Arguments

x	a numeric data frame or matrix where each column is a variable to be used for cluster analysis and each row is a data point.
kmax	a maximum number of clusters to be considered.
method	a character string indicating which clustering method to be used ("kmeans", "hclust_complete", "hclust_average", "hclust_single"). The default is "kmeans".
indexlist	a character string indicating which cluster validity indexes to be computed ("all", "STR", "PBM"). More than one indexes can be selected.
nstart	a maximum number of initial random sets for kmeans for method = "kmeans". The default is 100.
alpha	Dirichlet prior parameters $\alpha_2, \dots, \alpha_k$ where $\alpha_k$ is the parameter corresponding to "the probability of having k groups" (selecting each $\alpha_k$ between 0 to 30 is recommended and using the other parameter mult.alpha to be its multiplier. The default is "default".)
mult.alpha	the power $s$ from $n^s$ to be multiplied to the Dirichlet prior parameters alpha (selecting mult.alpha in $[\theta, 1)$ is recommended). The default is $\frac{1}{2}$ .

### Details

BCVI-STRPBM is defined as follows.

Let

$$r_k(\mathbf{x}) = \frac{\text{CVI}(\mathbf{k}) - \min_j \text{CVI}(\mathbf{j})}{\sum_{i=2}^{\mathbf{K}} (\text{CVI}(\mathbf{i}) - \min_j \text{CVI}(\mathbf{j}))}$$



where CVI is either STR or PBM index.  
Assume that

$$f(\mathbf{x}|\mathbf{p}) = C(\mathbf{p}) \prod_{k=2}^K p_k^{nr_k(x)}$$

represents the conditional probability density function of the dataset given  $\mathbf{p}$ , where  $C(\mathbf{p})$  is the normalizing constant. Assume further that  $\mathbf{p}$  follows a Dirichlet prior distribution with parameters  $\alpha = (\alpha_2, \dots, \alpha_K)$ . The posterior distribution of  $\mathbf{p}$  still remains a Dirichlet distribution with parameters  $(\alpha_2 + nr_2(\mathbf{x}), \dots, \alpha_K + nr_K(\mathbf{x}))$ .

The BCVI is then defined as

$$BCVI(k) = E[p_k|\mathbf{x}] = \frac{\alpha_k + nr_k(\mathbf{x})}{\alpha_0 + n}$$

where  $\alpha_0 = \sum_{k=2}^K \alpha_k$ .

The variance of  $p_k$  can be computed as

$$Var(p_k|\mathbf{x}) = \frac{(\alpha_k + nr_k(x))(\alpha_0 + n - \alpha_k - nr_k(x))}{(\alpha_0 + n)^2(\alpha_0 + n + 1)}.$$

### Value

BCVI	the dataframe where the first and the second columns are the number of groups k and $BCVI(k)$ , respectively, for k from 2 to kmax.
VAR	the data frame where the first and the second columns are the number of groups k and the variance of $p_k$ , respectively, for k from 2 to kmax.
CVI	the data frame where the first and the second columns are the number of groups k and the original $STR(k)$ or $PBM(k)$ , respectively, for k from 2 to kmax.

### Author(s)

Nathakhun Wiroonsri and Onthada Preedasawakul

### References

M. K. Pakhira, S. Bandyopadhyay and U. Maulik, "Validity index for crisp and fuzzy clusters," *Pattern Recogn* 37(3):487–501 (2004).

A. Starczewski, "A new validity index for crisp clusters," *Pattern Anal Applic* 20, 687–700 (2017).

O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, *Computational Statistics & Data Analysis*, 202, 108053, 2025. doi:10.1016/j.csda.2024.108053

### See Also

[B2\\_data](#), [B\\_TANG.IDX](#), [B\\_WP.IDX](#), [B\\_Wvalid](#), [B\\_DB.IDX](#)

## Examples

```

library(BayesCVI)

# The data included in this package.
data = B2_data[,1:2]

# alpha
aalpha = c(5,5,5,20,20,20,0.5,0.5,0.5)

B.STRPBM = B_STRPBM.IDX(x = scale(data), kmax=10, method = "kmeans",
                        indexlist = "all", nstart = 100, alpha = aalpha, mult.alpha = 1/2)

# plot the BCVI-STR

pplot = plot_BCVI(B.STRPBM$STR)
pplot$plot_index
pplot$plot_BCVI
pplot$error_bar_plot

# plot the BCVI-PBM

pplot = plot_BCVI(B.STRPBM$PBM)
pplot$plot_index
pplot$plot_BCVI
pplot$error_bar_plot

```

---

B\_TANG.IDX

*BCVI-Tang index*

---

## Description

Compute Bayesian cluster validity index (BCVI) from two to  $k_{\max}$  groups using Tang as the underlying cluster validity index (CVI) with the user's selected Dirichlet prior parameters. The full detail of BCVI can be found in the paper Wiroonsri and Preedasawakul (2024).

## Usage

```

B_TANG.IDX(x, kmax, method = "FCM", fzm = 2, nstart = 20,
           iter = 100, alpha = "default", mult.alpha = 1/2)

```

## Arguments

x	a numeric data frame or matrix where each column is a variable to be used for cluster analysis and each row is a data point.
kmax	a maximum number of clusters to be considered.
method	a character string indicating which clustering method to be used ("FCM" or "EM"). The default is "FCM".

fzm	a number greater than 1 giving the degree of fuzzification for method = "FCM". The default is 2.
nstart	a maximum number of initial random sets for FCM for method = "FCM". The default is 20.
iter	a maximum number of iterations for method = "FCM". The default is 100.
alpha	Dirichlet prior parameters $\alpha_2, \dots, \alpha_k$ where $\alpha_k$ is the parameter corresponding to "the probability of having k groups" (selecting each $\alpha_k$ between 0 to 30 is recommended and using the other parameter mult.alpha to be its multiplier. The default is "default").
mult.alpha	the power $s$ from $n^s$ to be multiplied to the Dirichlet prior parameters alpha (selecting mult.alpha in $[\emptyset, 1)$ is recommended). The default is $\frac{1}{2}$ .

### Details

BCVI-TANG is defined as follows.

Let

$$r_k(\mathbf{x}) = \frac{\max_j \mathbf{TANG}(j) - \mathbf{TANG}(k)}{\sum_{i=2}^K (\max_j \mathbf{TANG}(j) - \mathbf{TANG}(i))}.$$

Assume that

$$f(\mathbf{x}|\mathbf{p}) = C(\mathbf{p}) \prod_{k=2}^K p_k^{nr_k(x)}$$

represents the conditional probability density function of the dataset given  $\mathbf{p}$ , where  $C(\mathbf{p})$  is the normalizing constant. Assume further that  $\mathbf{p}$  follows a Dirichlet prior distribution with parameters  $\boldsymbol{\alpha} = (\alpha_2, \dots, \alpha_K)$ . The posterior distribution of  $\mathbf{p}$  still remains a Dirichlet distribution with parameters  $(\alpha_2 + nr_2(\mathbf{x}), \dots, \alpha_K + nr_K(\mathbf{x}))$ .

The BCVI is then defined as

$$BCVI(k) = E[p_k|\mathbf{x}] = \frac{\alpha_k + nr_k(\mathbf{x})}{\alpha_0 + n}$$

where  $\alpha_0 = \sum_{k=2}^K \alpha_k$ .

The variance of  $p_k$  can be computed as

$$Var(p_k|\mathbf{x}) = \frac{(\alpha_k + nr_k(x))(\alpha_0 + n - \alpha_k - nr_k(x))}{(\alpha_0 + n)^2(\alpha_0 + n + 1)}.$$

### Value

BCVI	the dataframe where the first and the second columns are the number of groups k and $BCVI(k)$ , respectively, for k from 2 to kmax.
VAR	the data frame where the first and the second columns are the number of groups k and the variance of $p_k$ , respectively, for k from 2 to kmax.
CVI	the data frame where the first and the second columns are the number of groups k and the original $\mathbf{TANG}(k)$ , respectively, for k from 2 to kmax.

**Author(s)**

Nathakhun Wiroonsri and Onthada Preedasawakul

**References**

Y. Tang, F. Sun, and Z. Sun, “Improved validation index for fuzzy clustering,” in Proceedings of the 2005, American Control Conference, 2005., pp. 1120–1125 vol. 2, 2005. <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1470111&isnumber=31519>

O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, Computational Statistics & Data Analysis, 202, 108053, 2025. [doi:10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

**See Also**

[B7\\_data](#), [B\\_DI.IDX](#), [B\\_WP.IDX](#), [B\\_Wvalid](#), [B\\_DB.IDX](#)

**Examples**

```
library(BayesCVI)

# The data included in this package.
data = B7_data[,1:2]

# alpha
aalpha = c(5,5,5,20,20,20,0.5,0.5,0.5)

B.TANG = B_TANG.IDX(x = scale(data), kmax =10, method = "FCM", fzm = 2,
                    nstart = 20, iter = 100, alpha = aalpha, mult.alpha = 1/2)

# plot the BCVI

pplot = plot_BCVI(B.TANG)
pplot$plot_index
pplot$plot_BCVI
pplot$error_bar_plot
```

---

B\_WL.IDX

*BCVI-Wu and Li (WL) index*

---

**Description**

Compute Bayesian cluster validity index (BCVI) from two to kmax groups using Wu and Li (WL) as the underling cluster validity index (CVI) with the user’s selected Dirichlet prior parameters. The full detail of BCVI can be found in the paper Wiroonsri and Preedasawakul (2024).

**Usage**

```
B_WL.IDX(x, kmax, method = "FCM", fzm = 2, nstart = 20,
         iter = 100, alpha = "default", mult.alpha = 1/2)
```

**Arguments**

x	a numeric data frame or matrix where each column is a variable to be used for cluster analysis and each row is a data point.
kmax	a maximum number of clusters to be considered.
method	a character string indicating which clustering method to be used ("FCM" or "EM"). The default is "FCM".
fzm	a number greater than 1 giving the degree of fuzzification for method = "FCM". The default is 2.
nstart	a maximum number of initial random sets for FCM for method = "FCM". The default is 20.
iter	a maximum number of iterations for method = "FCM". The default is 100.
alpha	Dirichlet prior parameters $\alpha_2, \dots, \alpha_k$ where $\alpha_k$ is the parameter corresponding to "the probability of having k groups" (selecting each $\alpha_k$ between 0 to 30 is recommended and using the other parameter mult.alpha to be its multiplier. The default is "default".)
mult.alpha	the power $s$ from $n^s$ to be multiplied to the Dirichlet prior parameters alpha (selecting mult.alpha in $[\emptyset, 1)$ is recommended). The default is $\frac{1}{2}$ .

**Details**

BCVI-WL is defined as follows.

Let

$$r_k(\mathbf{x}) = \frac{\max_j \mathbf{WL}(j) - \mathbf{WL}(k)}{\sum_{i=2}^K (\max_j \mathbf{WL}(j) - \mathbf{WL}(i))}$$

Assume that

$$f(\mathbf{x}|\mathbf{p}) = C(\mathbf{p}) \prod_{k=2}^K p_k^{nr_k(x)}$$

represents the conditional probability density function of the dataset given  $\mathbf{p}$ , where  $C(\mathbf{p})$  is the normalizing constant. Assume further that  $\mathbf{p}$  follows a Dirichlet prior distribution with parameters  $\boldsymbol{\alpha} = (\alpha_2, \dots, \alpha_K)$ . The posterior distribution of  $\mathbf{p}$  still remains a Dirichlet distribution with parameters  $(\alpha_2 + nr_2(\mathbf{x}), \dots, \alpha_K + nr_K(\mathbf{x}))$ .

The BCVI is then defined as

$$BCVI(k) = E[p_k|\mathbf{x}] = \frac{\alpha_k + nr_k(\mathbf{x})}{\alpha_0 + n}$$

where  $\alpha_0 = \sum_{k=2}^K \alpha_k$ .

The variance of  $p_k$  can be computed as

$$Var(p_k|\mathbf{x}) = \frac{(\alpha_k + nr_k(x))(\alpha_0 + n - \alpha_k - nr_k(x))}{(\alpha_0 + n)^2(\alpha_0 + n + 1)}$$

**Value**

BCVI	the dataframe where the first and the second columns are the number of groups $k$ and $BCVI(k)$ , respectively, for $k$ from 2 to $k_{max}$ .
VAR	the data frame where the first and the second columns are the number of groups $k$ and the variance of $p_k$ , respectively, for $k$ from 2 to $k_{max}$ .
CVI	the data frame where the first and the second columns are the number of groups $k$ and the original $WL(k)$ , respectively, for $k$ from 2 to $k_{max}$ .

**Author(s)**

Nathakhun Wiroonsri and Onthada Preedasawakul

**References**

C. H. Wu, C. S. Ouyang, L. W. Chen, and L. W. Lu, "A new fuzzy clustering validity index with a median factor for centroid-based clustering," IEEE Transactions on Fuzzy Systems, vol. 23, no. 3, pp. 701–718, 2015. <https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6811211&isnumber=7115244>

O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, Computational Statistics & Data Analysis, 202, 108053, 2025. [doi:10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

**See Also**

[B7\\_data](#), [B\\_TANG.IDX](#), [B\\_WP.IDX](#), [B\\_Wvalid](#), [B\\_DB.IDX](#)

**Examples**

```
library(BayesCVI)

# The data included in this package.
data = B7_data[,1:2]

# alpha
aalpha = c(5,5,5,20,20,20,0.5,0.5,0.5)

B.WL = B_WL.IDX(x = scale(data), kmax =10, method = "FCM", fzm = 2,
               nstart = 20, iter = 100, alpha = aalpha, mult.alpha = 1/2)

# plot the BCVI

pplot = plot_BCVI(B.WL)
pplot$plot_index
pplot$plot_BCVI
pplot$error_bar_plot
```

B\_WP.IDX

*BCVI-Wiroonsri and Preedasawakul (WP) index***Description**

Compute Bayesian cluster validity index (BCVI) from two to kmax groups using Wiroonsri and Preedasawakul (WP) as the underlying cluster validity index (CVI) with the user's selected Dirichlet prior parameters. The full detail of BCVI can be found in the paper Wiroonsri and Preedasawakul (2024).

**Usage**

```
B_WP.IDX(x, kmax, corr = "pearson", method = "FCM", fzm = 2,
         gamma = (fzm^2 * 7)/4, sampling = 1, iter = 100, nstart = 20,
         NCstart = TRUE, alpha = "default", mult.alpha = 1/2)
```

**Arguments**

x	a numeric data frame or matrix where each column is a variable to be used for cluster analysis and each row is a data point.
kmax	a maximum number of clusters to be considered.
corr	a character string indicating which correlation coefficient is to be computed ("pearson", "kendall" or "spearman"). The default is "pearson".
method	a character string indicating which clustering method to be used ("FCM" or "EM"). The default is "FCM".
fzm	a number greater than 1 giving the degree of fuzzification for method = "FCM". The default is 2.
gamma	adjusted fuzziness parameter for indexlist = ("WP", "WPC", "WPCI1", "WPCI2"). The default is computed from $7fzm^2/4$ .
sampling	a number greater than 0 and less than or equal to 1 indicating the undersampling proportion of data to be used. This argument is intended for handling a large dataset. The default is 1.
iter	a maximum number of iterations for method = "FCM". The default is 100.
nstart	a maximum number of initial random sets for FCM for method = "FCM". The default is 20.
NCstart	logical for indexlist = ("WP", "WPC", "WPCI1", "WPCI2"), if TRUE, the WP correlation at c=1 is defined as an adjusted sd of the distances between all data points and their mean. Otherwise, the WP correlation at c=1 is defined as 0.
alpha	Dirichlet prior parameters $\alpha_2, \dots, \alpha_k$ where $\alpha_k$ is the parameter corresponding to "the probability of having k groups" (selecting each $\alpha_k$ between 0 to 30 is recommended and using the other parameter mult.alpha to be its multiplier. The default is "default".)
mult.alpha	the power $s$ from $n^s$ to be multiplied to the Dirichlet prior parameters alpha (selecting mult.alpha in $[0, 1)$ is recommended). The default is $\frac{1}{2}$ .

### Details

BCVI-WP is defined as follows. Let

$$r_k(\mathbf{x}) = \frac{\mathbf{WP}(k) - \min_j \mathbf{WP}(j)}{\sum_{i=2}^K (\mathbf{WP}(i) - \min_j \mathbf{WP}(j))}$$

Assume that

$$f(\mathbf{x}|\mathbf{p}) = C(\mathbf{p}) \prod_{k=2}^K p_k^{nr_k(x)}$$

represents the conditional probability density function of the dataset given  $\mathbf{p}$ , where  $C(\mathbf{p})$  is the normalizing constant. Assume further that  $\mathbf{p}$  follows a Dirichlet prior distribution with parameters  $\alpha = (\alpha_2, \dots, \alpha_K)$ . The posterior distribution of  $\mathbf{p}$  still remains a Dirichlet distribution with parameters  $(\alpha_2 + nr_2(\mathbf{x}), \dots, \alpha_K + nr_K(\mathbf{x}))$ .

The BCVI is then defined as

$$BCVI(k) = E[p_k|\mathbf{x}] = \frac{\alpha_k + nr_k(\mathbf{x})}{\alpha_0 + n}$$

where  $\alpha_0 = \sum_{k=2}^K \alpha_k$ .

The variance of  $p_k$  can be computed as

$$Var(p_k|\mathbf{x}) = \frac{(\alpha_k + nr_k(x))(\alpha_0 + n - \alpha_k - nr_k(x))}{(\alpha_0 + n)^2(\alpha_0 + n + 1)}.$$

### Value

BCVI	the dataframe where the first and the second columns are the number of groups $k$ and $BCVI(k)$ , respectively, for $k$ from 2 to $kmax$ .
VAR	the data frame where the first and the second columns are the number of groups $k$ and the variance of $p_k$ , respectively, for $k$ from 2 to $kmax$ .
CVI	the data frame where the first and the second columns are the number of groups $k$ and the original $WP(k)$ , respectively, for $k$ from 2 to $kmax$ .

### Author(s)

Nathakhun Wiroonsri and Onthada Preedasawakul

### References

- N. Wiroonsri, O. Preedasawakul, "A correlation-based fuzzy cluster validity index with secondary options detector". [doi:10.48550/arXiv.2308.14785](https://doi.org/10.48550/arXiv.2308.14785)
- O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, Computational Statistics & Data Analysis, 202, 108053, 2025. [doi:10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

### See Also

[B7\\_data](#), [B\\_TANG.IDX](#), [B\\_XB.IDX](#), [B\\_Wvalid](#), [B\\_DB.IDX](#)



**Examples**

```

library(BayesCVI)

# The data included in this package.
data = B7_data[,1:2]

# alpha
aalpha = c(20,20,20,5,5,5,0.5,0.5,0.5)

B.WP = B_WP.IDX(x = scale(data), kmax = 10, corr = "pearson", method = "FCM",
               fzm = 2, sampling = 1, iter = 100, nstart = 20, NCstart = TRUE,
               alpha = aalpha, mult.alpha = 1/2)

# plot the BCVI

pplot = plot_BCVI(B.WP)
pplot$plot_index
pplot$plot_BCVI
pplot$error_bar_plot

```

B\_Wvalid

*BCVI-Wiroonsri (WI) index***Description**

Compute Bayesian cluster validity index (BCVI) from two to  $k_{\max}$  groups using Wiroonsri (WI) as the underlying cluster validity index (CVI) with the user's selected Dirichlet prior parameters. The full detail of BCVI can be found in the paper Wiroonsri and Preedasawakul (2024).

**Usage**

```

B_Wvalid(x, kmax, method = "kmeans", corr = "pearson", nstart = 100,
         sampling = 1, NCstart = TRUE, alpha = "default", mult.alpha = 1/2)

```

**Arguments**

x	a numeric data frame or matrix where each column is a variable to be used for cluster analysis and each row is a data point.
kmax	a maximum number of clusters to be considered.
method	a character string indicating which clustering method to be used ("kmeans", "hclust_complete", "hclust_average", "hclust_single"). The default is "kmeans".
corr	a character string indicating which correlation coefficient is to be computed ("pearson", "kendall" or "spearman"). The default is "pearson".
nstart	a maximum number of initial random sets for kmeans for method = "kmeans". The default is 100.

sampling	a number greater than 0 and less than or equal to 1 indicating the undersampling proportion of data to be used. This argument is intended for handling a large dataset. The default is 1.
NCstart	logical for <code>indexlist</code> includes the "NC", "NCI", "NCI1", and "NCI2"), if TRUE, the NC correlation at $k=1$ is defined as the ratio introduced in the reference. Otherwise, it is assigned as $\emptyset$ .
alpha	Dirichlet prior parameters $\alpha_2, \dots, \alpha_k$ where $\alpha_k$ is the parameter corresponding to "the probability of having k groups" (selecting each $\alpha_k$ between 0 to 30 is recommended and using the other parameter <code>mult.alpha</code> to be its multiplier. The default is "default").
mult.alpha	the power $s$ from $n^s$ to be multiplied to the Dirichlet prior parameters <code>alpha</code> (selecting <code>mult.alpha</code> in $[\emptyset, 1)$ is recommended). The default is $\frac{1}{2}$ .

### Details

BCVI-WI is defined as follows. Let

$$r_k(\mathbf{x}) = \frac{\mathbf{WI}(k) - \min_j \mathbf{WI}(j)}{\sum_{i=2}^K (\mathbf{WI}(i) - \min_j \mathbf{WI}(j))}$$

Assume that

$$f(\mathbf{x}|\mathbf{p}) = C(\mathbf{p}) \prod_{k=2}^K p_k^{nr_k(x)}$$

represents the conditional probability density function of the dataset given  $\mathbf{p}$ , where  $C(\mathbf{p})$  is the normalizing constant. Assume further that  $\mathbf{p}$  follows a Dirichlet prior distribution with parameters  $\boldsymbol{\alpha} = (\alpha_2, \dots, \alpha_K)$ . The posterior distribution of  $\mathbf{p}$  still remains a Dirichlet distribution with parameters  $(\alpha_2 + nr_2(\mathbf{x}), \dots, \alpha_K + nr_K(\mathbf{x}))$ .

The BCVI is then defined as

$$BCVI(k) = E[p_k|\mathbf{x}] = \frac{\alpha_k + nr_k(\mathbf{x})}{\alpha_0 + n}$$

where  $\alpha_0 = \sum_{k=2}^K \alpha_k$ .

The variance of  $p_k$  can be computed as

$$Var(p_k|\mathbf{x}) = \frac{(\alpha_k + nr_k(x))(\alpha_0 + n - \alpha_k - nr_k(x))}{(\alpha_0 + n)^2(\alpha_0 + n + 1)}.$$

### Value

BCVI	the dataframe where the first and the second columns are the number of groups $k$ and $BCVI(k)$ , respectively, for $k$ from 2 to <code>kmax</code> .
VAR	the data frame where the first and the second columns are the number of groups $k$ and the variance of $p_k$ , respectively, for $k$ from 2 to <code>kmax</code> .
CVI	the data frame where the first and the second columns are the number of groups $k$ and the original $WI(k)$ , respectively, for $k$ from 2 to <code>kmax</code> .

**Author(s)**

Nathakhun Wiroonsri and Onthada Preedasawakul

**References**

N. Wiroonsri, "Clustering performance analysis using a new correlation based cluster validity index," *Pattern Recognition*, 145, 109910, 2024. doi:10.1016/j.patcog.2023.109910

O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, *Computational Statistics & Data Analysis*, 202, 108053, 2025. doi:10.1016/j.csda.2024.108053

**See Also**

[B2\\_data](#), [B\\_TANG.IDX](#), [B\\_WP.IDX](#), [B\\_STRPBM.IDX](#), [B\\_DB.IDX](#)

**Examples**

```
library(BayesCVI)

# The data included in this package.
data = B2_data[,1:2]

# alpha
aalpha = c(5,5,5,20,20,20,0.5,0.5,0.5)

B.WI = B_Wvalid(x = scale(data), kmax = 10, method = "kmeans", corr = "pearson",
               nstart = 100, sampling = 1, NCstart = TRUE, alpha = aalpha,
               mult.alpha = 1/2)

# plot the BCVI

pplot = plot_BCVI(B.WI)
pplot$plot_index
pplot$plot_BCVI
pplot$error_bar_plot
```

---

B\_XB.IDX

*BCVI-Xie and Beni (XB) index*

---

**Description**

Compute Bayesian cluster validity index (BCVI) from two to kmax groups using Xie and Beni (XB) as the underlying cluster validity index (CVI) with the user's selected Dirichlet prior parameters. The full detail of BCVI can be found in the paper Wiroonsri and Preedasawakul (2024).

**Usage**

```
B_XB.IDX(x, kmax, method = "FCM", fzm = 2, nstart = 20,
         iter = 100, alpha = "default", mult.alpha = 1/2)
```

**Arguments**

x	a numeric data frame or matrix where each column is a variable to be used for cluster analysis and each row is a data point.
kmax	a maximum number of clusters to be considered.
method	a character string indicating which clustering method to be used ("FCM" or "EM"). The default is "FCM".
fzm	a number greater than 1 giving the degree of fuzzification for method = "FCM". The default is 2.
nstart	a maximum number of initial random sets for FCM for method = "FCM". The default is 20.
iter	a maximum number of iterations for method = "FCM". The default is 100.
alpha	Dirichlet prior parameters $\alpha_2, \dots, \alpha_k$ where $\alpha_k$ is the parameter corresponding to "the probability of having k groups" (selecting each $\alpha_k$ between 0 to 30 is recommended and using the other parameter mult.alpha to be its multiplier. The default is "default".)
mult.alpha	the power $s$ from $n^s$ to be multiplied to the Dirichlet prior parameters alpha (selecting mult.alpha in $[\theta, 1)$ is recommended). The default is $\frac{1}{2}$ .

**Details**

BCVI-XB is defined as follows.

Let

$$r_k(\mathbf{x}) = \frac{\max_j \mathbf{XB}(j) - \mathbf{XB}(k)}{\sum_{i=2}^K (\max_j \mathbf{XB}(j) - \mathbf{XB}(i))}$$

Assume that

$$f(\mathbf{x}|\mathbf{p}) = C(\mathbf{p}) \prod_{k=2}^K p_k^{nr_k(x)}$$

represents the conditional probability density function of the dataset given  $\mathbf{p}$ , where  $C(\mathbf{p})$  is the normalizing constant. Assume further that  $\mathbf{p}$  follows a Dirichlet prior distribution with parameters  $\boldsymbol{\alpha} = (\alpha_2, \dots, \alpha_K)$ . The posterior distribution of  $\mathbf{p}$  still remains a Dirichlet distribution with parameters  $(\alpha_2 + nr_2(\mathbf{x}), \dots, \alpha_K + nr_K(\mathbf{x}))$ .

The BCVI is then defined as

$$BCVI(k) = E[p_k|\mathbf{x}] = \frac{\alpha_k + nr_k(\mathbf{x})}{\alpha_0 + n}$$

where  $\alpha_0 = \sum_{k=2}^K \alpha_k$ .

The variance of  $p_k$  can be computed as

$$Var(p_k|\mathbf{x}) = \frac{(\alpha_k + nr_k(x))(\alpha_0 + n - \alpha_k - nr_k(x))}{(\alpha_0 + n)^2(\alpha_0 + n + 1)}$$

**Value**

BCVI	the dataframe where the first and the second columns are the number of groups $k$ and $BCVI(k)$ , respectively, for $k$ from 2 to $k_{max}$ .
VAR	the data frame where the first and the second columns are the number of groups $k$ and the variance of $p_k$ , respectively, for $k$ from 2 to $k_{max}$ .
CVI	the data frame where the first and the second columns are the number of groups $k$ and the original $XB(k)$ , respectively, for $k$ from 2 to $k_{max}$ .

**Author(s)**

Nathakhun Wiroonsri and Onthada Preedasawakul

**References**

- X. Xie and G. Beni, "A validity measure for fuzzy clustering," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 13, no. 8, pp. 841–847, 1991.
- O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, Computational Statistics & Data Analysis, 202, 108053, 2025. [doi:10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

**See Also**

[B7\\_data](#), [B\\_TANG.IDX](#), [B\\_WP.IDX](#), [B\\_Wvalid](#), [B\\_DB.IDX](#)

**Examples**

```
library(BayesCVI)

# The data included in this package.
data = B7_data[,1:2]

# alpha
aalpaha = c(5,5,5,20,20,20,0.5,0.5,0.5)

B.XB = B_XB.IDX(x = scale(data), kmax =10, method = "FCM",
               fzm = 2, nstart = 20, iter = 100, alpha = aalalpha, mult.alpha = 1/2)

# plot the BCVI

pplot = plot_BCVI(B.XB)
pplot$plot_index
pplot$plot_BCVI
pplot$error_bar_plot
```

plot\_BCVI

*Plots for visualizing BCVI***Description**

Plot Bayesian cluster validity index (BCVI) with and without standard deviation error bars and the underlying index.

**Usage**

```
plot_BCVI(B.result, mult.err.bar = 2)
```

**Arguments**

`B.result` a result from one of the functions `B_XB.IDX`, `B_Wvalid`, `B_WP.IDX`, `B_WL.IDX`, `B_TANG.IDX`, `B_STRPBM.IDX`, `B_SF.IDX`, `B_PBM.IDX`, `B_PB.IDX`, `B_KWON.IDX`, `B_KWON2.IDX`, `B_KPBM.IDX`, `B_HF.IDX`, `B_GC.IDX`, `B_DI.IDX`, `B_DB.IDX`, `B_CSL.IDX`, `B_CH.IDX`, `B_CCV.IDX` and `B_BayesCVIs.IDX`

`mult.err.bar` a multiplier of the stadard deviations to be used for plotting error bars

**Details**

BCVI is defined as follows.

Let

$$r_k(\mathbf{x}) = \frac{\max_j \text{CVI}(\mathbf{j}) - \text{CVI}(\mathbf{k})}{\sum_{i=2}^{\mathbf{K}} (\max_j \text{CVI}(\mathbf{j}) - \text{CVI}(\mathbf{i}))}$$

for a cluster validity index (CVI) such that the smallest value indicates the optimal number of clusters and

$$r_k(\mathbf{x}) = \frac{\text{CVI}(\mathbf{k}) - \min_j \text{CVI}(\mathbf{j})}{\sum_{i=2}^{\mathbf{K}} (\text{CVI}(\mathbf{i}) - \min_j \text{CVI}(\mathbf{j}))}$$

for a CVI such that the largest indicates the optimal number of clusters. Assume that

$$f(\mathbf{x}|\mathbf{p}) = C(\mathbf{p}) \prod_{k=2}^{\mathbf{K}} p_k^{nr_k(\mathbf{x})}$$

represents the conditional probability density function of the dataset given  $\mathbf{p}$ , where  $C(\mathbf{p})$  is the normalizing constant. Assume further that  $\mathbf{p}$  follows a Dirichlet prior distribution with parameters  $\boldsymbol{\alpha} = (\alpha_2, \dots, \alpha_K)$ . The posterior distribution of  $\mathbf{p}$  still remains a Dirichlet distribution with parameters  $(\alpha_2 + nr_2(\mathbf{x}), \dots, \alpha_K + nr_K(\mathbf{x}))$ .

The BCVI is then defined as

$$BCVI(k) = E[p_k|\mathbf{x}] = \frac{\alpha_k + nr_k(\mathbf{x})}{\alpha_0 + n}$$

where  $\alpha_0 = \sum_{k=2}^{\mathbf{K}} \alpha_k$ .

The variance of  $p_k$  can be computed as

$$\text{Var}(p_k|\mathbf{x}) = \frac{(\alpha_k + nr_k(x))(\alpha_0 + n - \alpha_k - nr_k(x))}{(\alpha_0 + n)^2(\alpha_0 + n + 1)}.$$

### Value

plot_index	a plot of the underlying index for the number of groups from 2 to $kmax$ according to B.result
plot_BCVI	a plot of BCVI for the number of groups from 2 to $kmax$ according to B.result
error_bar_plot	a plot of BCVI with error bars for the number of groups from 2 to $kmax$ according to B.result

### Author(s)

Nathakhun Wiroonsri and Onthada Preedasawakul

### References

O. Preedasawakul, and N. Wiroonsri, A Bayesian Cluster Validity Index, Computational Statistics & Data Analysis, 202, 108053, 2025. [doi:10.1016/j.csda.2024.108053](https://doi.org/10.1016/j.csda.2024.108053)

### See Also

[B\\_STRPBM.IDX](#), [B\\_TANG.IDX](#), [B\\_XB.IDX](#), [B\\_Wvalid](#), [B\\_WP.IDX](#), [B\\_DB.IDX](#)

### Examples

```
library(BayesCVI)
library(UniversalCVI)

##Soft clustering

# The data included in this package.
data = B7_data[,1:2]

# alpha
alpha = c(5,5,5,20,20,20,0.5,0.5,0.5)

B.XB = B_XB.IDX(x = scale(data), kmax =10, method = "FCM", fzm = 2,
               nstart = 20, iter = 100, alpha = alpha, mult.alpha = 1/2)

# plot the BCVI

pplot = plot_BCVI(B.XB)
pplot$plot_index
pplot$plot_BCVI
pplot$error_bar_plot

## Hard clustering
```

```
# The data included in this package.
data = B2_data[,1:2]

K.STR = STRPBM.IDX(scale(data), kmax = 10, kmin = 2, method = "kmeans",
  indexlist = "STR", nstart = 100)

# WP.IDX values
result = K.STR$STR$STR

aalpha = c(20,20,20,5,5,5,0.5,0.5,0.5)
B.STR = BayesCVIs(CVI = result,
  n = nrow(data),
  kmax = 10,
  opt.pt = "max",
  alpha = aalpha,
  mult.alpha = 1/2)

# plot the BCVI

pplot = plot_BCVI(B.STR)
pplot$plot_index
pplot$plot_BCVI
pplot$error_bar_plot
```



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