

# Package ‘biplotEZ’

July 8, 2024

**Title** EZ-to-Use Biplots

**Version** 2.0

**Description** Provides users with an EZ-to-use platform for representing data with biplots. Currently principal component analysis (PCA) and canonical variate analysis (CVA) biplots are included. This is accompanied by various formatting options for the samples and axes. Alpha-bags and concentration ellipses are included for visual enhancements and interpretation. For an extensive discussion on the topic, see Gower, J.C., Lubbe, S. and le Roux, N.J. (2011, ISBN: 978-0-470-01255-0) Understanding Biplots. Wiley: Chichester.

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---

`alpha.bags`*Create alpha bags*

---

**Description**

This function produces  $\alpha$ -bags, which is a useful graphical summary of the scatter plot. The alpha-bag refers to a contour which contains  $\alpha\%$  of the observations.

**Usage**

```
alpha.bags(bp, alpha = 0.95, which = NULL, col = ez.col[which], lty = 1,  
lwd = 1, max = 2500, trace = TRUE, opacity = 0.25, outlying=FALSE)
```

**Arguments**

<code>bp</code>	an object of class biplot.
<code>alpha</code>	numeric vector between 0 and 1 to determine coverage of the bag ( $\alpha$ ), with default 0.95.
<code>which</code>	numeric vector indicating the selection of groups or classes to be fitted with $\alpha$ -bags.
<code>col</code>	vector of colours for the $\alpha$ -bags. Multiple $\alpha$ bags for one group will be displayed in the same colour.
<code>lty</code>	vector of line types for the $\alpha$ -bags. The same line type will be used per value of $\alpha$ .
<code>lwd</code>	vector of line widths for the $\alpha$ -bags. The same line width will be used per value of $\alpha$ .
<code>max</code>	maximum number of samples to include in $\alpha$ -bag calculations, with default 2500. If more samples are in the group, a random sample of size <code>max</code> is taken for the computations.
<code>trace</code>	logical, indicating progress of computation.
<code>opacity</code>	level of opacity, with default 0.5.
<code>outlying</code>	logical indicating whether only outlying points should be plotted. Note the <code>which</code> argument may be overwritten when TRUE

**Value**

A list with the following components is available:

<code>alpha.bags</code>	list of coordinates for the $\alpha$ -bags for each group.
<code>col</code>	vector of colours for the $\alpha$ -bags.
<code>lty</code>	vector of line types for the $\alpha$ -bags.
<code>lwd</code>	vector of line widths for the $\alpha$ -bags.

## References

Gower, J., Gardner-Lubbe, S. & Le Roux, N. (2011, ISBN: 978-0-470-01255-0) *Understanding Biplots*. Chichester, England: John Wiley & Sons Ltd.

## Examples

```
biplot (iris[,1:4]) |> PCA(group.aes=iris[,5]) |> alpha.bags(alpha=0.95) |> plot()
biplot (iris[,1:4],group.aes=iris[,5]) |> PCA() |> alpha.bags(alpha=0.95) |> plot()
```

---

AoD

*Use the Analysis of Distance (AoD) method to construct the biplot*

---

## Description

This function appends the biplot object with elements resulting from using the AoD method.

## Usage

```
AoD(bp, classes=bp$classes, Dmat=NULL, dist.func=NULL,
dim.biplot = c(2,1,3), e.vects = 1:ncol(bp$X),
weighted = c("unweighted","weighted"), show.class.means = TRUE,
axes = c("regression","splines"), ...)
```

## Arguments

<code>bp</code>	an object of class <code>biplot</code> obtained from preceding function <code>biplot()</code> .
<code>classes</code>	a vector of the same length as the number of rows in the data matrix with the class indicator for the samples.
<code>Dmat</code>	the matrix of Euclidean embeddable distances between samples.
<code>dist.func</code>	a character string indicating which distance function is used to compute the Euclidean embeddable distances between samples. One of <code>NULL</code> (default) which computes the Euclidean distance or other functions that can be used for the <code>dist()</code> function.
<code>dim.biplot</code>	the dimension of the biplot. Only values 1, 2 and 3 are accepted, with default 2.
<code>e.vects</code>	the vector indicating which eigenvectors (canonical variates) should be plotted in the biplot, with default <code>1:dim.biplot</code> .
<code>weighted</code>	a character string indicating the weighting of the classes. One of "unweighted" for each class to receive equal weighting or "weighted" for each class to receive their class sizes as weights.
<code>show.class.means</code>	a logical value indicating whether to plot the class means on the biplot.
<code>axes</code>	a character string indicating the type of biplot axes to be used in the biplot. One of "regression" or "splines".
<code>...</code>	more arguments to <code>dist.func</code> .

**Value**

Object of class biplot

**Examples**

```
biplot(iris[,1:4]) |> AoD(classes=iris[,5])
# create a CVA biplot
biplot(iris[,1:4]) |> AoD(classes=iris[,5]) |> plot()
```

---

AoD.biplot

*Calculate elements for the Analysis of Distance (AoD) biplot*


---

**Description**

This function is used to construct the AoD biplot

**Usage**

```
## S3 method for class 'biplot'
AoD(
  bp,
  classes = bp$classes,
  Dmat = NULL,
  dist.func = NULL,
  dim.biplot = c(2, 1, 3),
  e.vects = 1:ncol(bp$X),
  weighted = c("unweighted", "weighted"),
  show.class.means = TRUE,
  axes = c("regression", "splines"),
  ...
)
```

**Arguments**

bp	an object of class biplot obtained from preceding function biplot().
classes	a vector of the same length as the number of rows in the data matrix with the class indicator for the samples.
Dmat	the matrix of Euclidean embeddable distances between samples.
dist.func	a character string indicating which distance function is used to compute the Euclidean embeddable distances between samples. One of NULL (default) which computes the Euclidean distance or other functions that can be used for the dist() function.
dim.biplot	the dimension of the biplot. Only values 1, 2 and 3 are accepted, with default 2.
e.vects	the vector indicating which eigenvectors (canonical variates) should be plotted in the biplot, with default 1:dim.biplot.

<code>weighted</code>	a character string indicating the weighting of the classes. One of "unweighted" for each class to receive equal weighting or "weighted" for each class to receive their class sizes as weights.
<code>show.class.means</code>	a logical value indicating whether to plot the class means on the biplot.
<code>axes</code>	a character string indicating the type of biplot axes to be used in the biplot. One of "regression" or "splines".
<code>...</code>	more arguments to <code>dist.func</code> .

**Value**

an object of class `biplot`.

**Examples**

```
biplot(iris) |> AoD(classes = iris[,5]) |> plot()
```

---

axes

*Aesthetics for biplot axes*

---

**Description**

This function allows formatting changes to axes.

**Usage**

```
axes(bp, X.names=colnames(bp$X), which = 1:bp$p, col = grey(0.7), lwd = 1, lty = 1,
label.dir = "Orthog", label.col = col, label.cex = 0.75, label.line = 0.1,
label.offset=rep(0,4), ticks = 5, tick.col = col, tick.size = 1, tick.label = TRUE,
tick.label.side = "below", tick.label.col = tick.col, tick.label.cex = 0.6,
predict.col = col, predict.lwd = lwd, predict.lty = lty, ax.names = X.names,
orthogx = 0, orthogy = 0, vectors = FALSE, unit.circle=FALSE)
```

**Arguments**

<code>bp</code>	an object of class <code>biplot</code> .
<code>X.names</code>	refers to the column names of <code>bp</code> to specify which axes to label.
<code>which</code>	integer-valued vector specifying which biplot axes are shown in a biplot. By default all <code>p</code> biplot axes are shown.
<code>col</code>	vector of size <code>p</code> specifying colours of labels of biplot axes. The default is <code>grey(0.7)</code> .
<code>lwd</code>	axis line width, with default 1.
<code>lty</code>	axis line type, with default 1.

<code>label.dir</code>	One of "Orthog" (default), "Hor" or "Paral" specifying titles of axes to appear orthogonal to the side of the figure; always horizontally or always parallel to the side of the figure.
<code>label.col</code>	axis label colour, with default, <code>col</code> .
<code>label.cex</code>	axis label expansion, with default <code>0.75</code> .
<code>label.line</code>	axis label written on which margin line, with default <code>0.1</code> .
<code>label.offset</code>	A four-component numeric vector controlling the distance a biplot axis title is printed from the side of the figure. Sides are numbered 1 to 4 according to R conventions clockwise starting from the bottom horizontal side. Default is <code>rep(0,4)</code>
<code>ticks</code>	integer-valued vector of size equal to the number of biplot axes to control the number of tickmarks on each individual biplot axis. Default is 5 for each axis.
<code>tick.col</code>	tick mark colour, with default <code>col</code> .
<code>tick.size</code>	positive integer-valued vector with specifying tick mark sizes, with default <code>1</code> .
<code>tick.label</code>	logical, whether axes should be labelled or not, with default <code>TRUE</code> .
<code>tick.label.side</code>	character vector specifying position of the tick label "below" or "above" the axis.
<code>tick.label.col</code>	tick mark label colour, with default <code>tick.col</code> .
<code>tick.label.cex</code>	tick mark label expansion, with default <code>0.6</code> .
<code>predict.col</code>	predicted samples colour, with default <code>col</code> .
<code>predict.lwd</code>	predicted samples line width, with default <code>lwd</code> .
<code>predict.lty</code>	predicted samples line type, with default <code>lty</code> .
<code>ax.names</code>	vector of size <code>p</code> containing user defined names for the variables.
<code>orthogx</code>	numeric vector of size <code>p</code> specifying the x-coordinate of the parallel transformation of each axis. Defaults to zero for each axis. Only used when the dimension of the biplot is two.
<code>orthogy</code>	numeric vector of size <code>p</code> specifying the y-coordinate of the parallel transformation of each axis. Defaults to zero for each axis. Only used when the dimension of the biplot is two.
<code>vectors</code>	logical, whether calibrated axes should be displayed on the biplot
<code>unit.circle</code>	logical, whether a unit circle should be displayed on the biplot

**Value**

A list with the following components is available:

<code>which</code>	vector of the columns displayed as axes.
<code>col</code>	vector of axis colours.
<code>lwd</code>	vector of axis line widths.
<code>lty</code>	vector of axis line types.
<code>label.dir</code>	direction of the axis labels.
<code>label.col</code>	vector of axis label colours.

label.cex	vector of axis labels expansions.
label.line	vector of axis label margin lines from axes.
ticks	vector representing the number of tick marks per axis.
tick.col	vector of tick mark colours.
tick.size	vector of tick mark sizes.
tick.label	vector of logical values indicating whether axes are labelled.
tick.label.side	vector specifying position of the tick label "below" or "above" the axis.
tick.label.col	vector of tick mark label colours.
tick.label.cex	vector of tick mark label expansions.
predict.col	vector of colours for the predicted samples.
predict.lty	vector of line types for the predicted samples.
predict.lwd	vector of line widths for the predicted samples.
names	vector of variable names defined by the user.
orthogx	vector of the horisontal translations for each axis.
orthogy	vector of the vertical translations for each axis.
calibrated.axis	whether to plot calibrated axis

### Examples

```
biplot(iris[,1:4]) |> PCA() |> axes(col="purple") |> plot()
biplot(iris[,1:4]) |> PCA() |> samples(col="purple",pch=15) |> axes() |> plot()
```

---

biplot

*First step to create a new biplot with **biplotEZ***

---

### Description

This function produces a list of elements to be used when producing a biplot, which provides a useful data analysis tool and allows the visual appraisal of the structure of large data matrices. Biplots are the multivariate analogue of scatter plots. They approximate the multivariate distribution of a sample in a few dimensions and they superimpose on this display representations of the variables on which the samples are measured.

### Usage

```
biplot(data, classes = NULL, group.aes = NULL, center = TRUE, scaled = FALSE,
Title = NULL)
```



**Arguments**

data	a data frame or numeric matrix containing all variables the user wants to analyse.
classes	a vector identifying class membership.
group.aes	a vector identifying groups for aesthetic formatting.
center	a logical value indicating whether data should be column centered, with default TRUE.
scaled	a logical value indicating whether data should be standardised to unit column variances, with default FALSE.
Title	the title of the biplot to be rendered, enter text in " ".

**Details**

This function is the entry-level function in `biplotEZ` to construct a biplot display. It initialises an object of class `biplot` which can then be piped to various other functions to build up the biplot display.

**Value**

A list with the following components is available:

X	the matrix of the centered and scaled numeric variables.
Xcat	the data frame of the categorical variables.
raw.X	the original data.
classes	the vector of category levels for the class variable. This is to be used for colour, pch and cex specifications.
na.action	the vector of observations that have been removed.
center	a logical value indicating whether $\mathbf{X}$ is centered.
scaled	a logical value indicating whether $\mathbf{X}$ is scaled.
means	the vector of means for each numeric variable.
sd	the vector of standard deviations for each numeric variable.
n	the number of observations.
p	the number of variables.
group.aes	the vector of category levels for the grouping variable. This is to be used for colour, pch and cex specifications.
g.names	the descriptive names to be used for group labels.
g	the number of groups.
Title	the title of the biplot rendered

## Useful links

The biplot display can be built up in four broad steps depending on the needs for the display. Firstly, choose an appropriate method to construct the display; Secondly, change the aesthetics of the display; Thirdly, append the display with supplementary features such as axes, samples and means; Finally, superimpose shapes, characters or elements onto the display.

### 1. Different types of biplots:

- `PCA()`: Principal Component Analysis biplot of various dimensions
- `CVA()`: Canonical Variate Analysis biplot
- `PCO()`: Principal Coordinate Analysis biplot
- `CA()`: Correspondence Analysis biplot
- `regress()`: Regression biplot method

### 2. Customise the biplot display with aesthetic functions:

- `samples()`: Change the formatting of sample points on the biplot display
- `axes()`: Change the formatting of the biplot axes

### 3. Supplement the existing biplot with additional axes, samples and group means:

- `newsamples()`: Add and change formatting of additional samples
- `newaxes()`: Add and change formatting of additional axes
- `means()`: Insert class means to the display, and format appropriately

### 4. Append the biplot display:

- `alpha.bags()`: Add  $\alpha$ -bags
- `ellipses()`: Add ellipses
- `density2D()`: Add 2D density regions

### Other useful links:

- `plot()`
- `fit.measures()`
- `legend.type()`
- `interpolate()`
- `prediction()`
- `classify()`
- `reflect()`
- `rotate()`

## References

Gabriel, K.R. (1971) The biplot graphic display of matrices with application to principal component analysis. *Biometrika*. 58(3):453–467. Gower, J., Gardner-Lubbe, S. & Le Roux, N. (2011, ISBN: 978-0-470-01255-0) *Understanding Biplots*. Chichester, England: John Wiley & Sons Ltd. Gower, J.C. & Hand, D.J.(1996, ISBN: 0-412-71630-5) *Biplots*. London: Chapman & Hall.

**Examples**

```
biplot(data = iris)
# create a PCA biplot
biplot(data = iris) |> PCA() |> plot()
```

---

**biplotEZ***biplotEZ: EZ-to-Use Biplots*

---

**Description****Details**

The goal of biplotEZ is to provide users an EZ-to-use platform for visually representing their data with biplots. Currently, this package includes principal component analysis (PCA) and canonical variate analysis (CVA) biplots. This is accompanied by various formatting options for the samples and axes. Alpha-bags and concentration ellipses are included for visual enhancements and interpretation.

**Details**

Package:	biplotEZ
Type:	Package
Version:	2.0
Date:	05-04-2024
License:	MIT
LazyLoad:	TRUE

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### Core Functions

- [biplot](#)
- [PCA](#)
- [CVA](#)
- [CA](#)

### Code Availability

The newest version of the package can be obtained on GitHub: <https://github.com/MuViSU/biplotEZ>

---

CA	<i>Correspondence Analysis (CA) method</i>
----	--

---

### Description

This function produces a list of elements to be used for CA biplot construction by approximation of the Pearson residuals.

### Usage

```
CA(bp, dim.biplot = c(2,1,3), e.vects = 1:ncol(bp$X), variant = "Princ",
  lambda.scal = FALSE)
```

### Arguments

bp	object of class <code>biplot</code> obtained from preceding function <code>biplot(center = FALSE)</code> . In order to maintain the frequency table, the input should not be centered or scaled. For CA, bp should be a contingency table.
dim.biplot	dimension of the biplot. Only values 1, 2 and 3 are accepted, with default 2.
e.vects	which eigenvectors (canonical variates) to extract, with default <code>1:dim.biplot</code> .
variant	which correspondence analysis variant, with default "Princ", presents a biplot with rows in principal coordinates and columns in standard coordinates. <code>variant = "Stand"</code> , presents a biplot with rows in standard coordinates and columns in principal coordinates. <code>variant = "symmetric"</code> , presents a symmetric biplot with row and column standard coordinates scaled equally by the singular values.
lambda.scal	logical value to request lambda-scaling, default is FALSE.

### Value

A list with the following components is available:

Z	Combined data frame of the row and column coordinates.
r	Numer of levels in the row factor.
c	Numer of levels in the column factor.

rowcoor	Row coordinates based on the selected variant.
colcoor	Column coordinates based on the selected variant.
P	Correspondence Matrix
Smat	Standardised Pearson residuals.
SVD	Singular value decomposition solution: d, u, v.
qual	Quality of the approximation.
lambda.val	The computed lambda value if lambda-scaling is requested.

### Examples

```
# Creating a CA biplot with rows in principal coordinates:
biplot(HairEyeColor[, ,2], center = FALSE) |> CA() |> plot()
# Creating a CA biplot with rows in standard coordinates:
biplot(HairEyeColor[, ,2], center = FALSE) |> CA(variant = "Stand") |>
samples(col=c("magenta", "purple"), pch=c(15,17), label.col="black") |> plot()
# Creating a CA biplot with rows and columns scaled equally:
biplot(HairEyeColor[, ,2], center = FALSE) |> CA(variant = "Symmetric") |>
samples(col=c("magenta", "purple"), pch=c(15,17), label.col="black") |> plot()
```

---

CA.biplot

*CA biplot*


---

### Description

Performs calculations for a CA biplot.

### Usage

```
## S3 method for class 'biplot'
CA(
  bp,
  dim.biplot = c(2, 1, 3),
  e.vects = 1:ncol(bp$X),
  variant = "Princ",
  lambda.scal = FALSE
)
```

### Arguments

bp	object of class biplot obtained from preceding function biplot(center = FALSE). In order to maintain the frequency table, the input should not be centered or scaled. For CA, bp should be a contingency table.
dim.biplot	dimension of the biplot. Only values 1, 2 and 3 are accepted, with default 2.
e.vects	which eigenvectors (canonical variates) to extract, with default 1:dim.biplot.

variant	which correspondence analysis variant, with default "Princ", presents a biplot with rows in principal coordinates and columns in standard coordinates. variant = "Stand", presents a biplot with rows in standard coordinates and columns in principal coordinates. variant = "symmetric", presents a symmetric biplot with row and column standard coordinates scaled equally by the singular values.
lambda.scal	logical value to request lambda-scaling, default is FALSE.

**Value**

an object of class CA, inherits from class biplot.

**Examples**

```
biplot(HairEyeColor[, ,2], center = FALSE) |> CA() |> plot()
```

---

 CATPCA

*Categorical Principal Component Analysis*


---

**Description**

Categorical Principal Component Analysis

**Usage**

```
CATPCA(bp, dim.biplot = c(2, 1, 3), e.vects = 1:ncol(bp$X),
group.aes = NULL, show.class.means = FALSE)
```

**Arguments**

bp	an object of class biplot obtained from preceding function biplot().
dim.biplot	dimension of the biplot. Only values 1, 2 and 3 are accepted, with default 2.
e.vects	which eigenvectors (principal components) to extract, with default 1:dim.biplot.
group.aes	vector of the same length as the number of rows in the data matrix for differentiated aesthetics for samples.
show.class.means	logical, indicating whether group means should be plotted in the biplot.

**Value**

an object of class biplot

**Examples**

```
CATPCA (iris)
```

---

classification	<i>Classification biplot method</i>
----------------	-------------------------------------

---

### Description

This function produces a list of elements to be used for constructing a classification biplot.

### Usage

```
classification(bp, Pmat, dim.biplot = c(2, 1, 3), e.vects = 1:ncol(bp$X),
group.aes=NULL, axes = "regression", col=ez.col, opacity=0.4, borders = FALSE)
```

### Arguments

bp	an object of class biplot obtained from preceding function biplot().
Pmat	a matrix containing the posterior probability for the classes
dim.biplot	dimension of the biplot. Only values 1, 2 and 3 are accepted, with default 2.
e.vects	which eigenvectors (principal components) to extract, with default 1:dim.biplot.
group.aes	vector of the same length as the number of rows in the data matrix for differentiated aesthetics for samples.
axes	type of axes, defaults to "regression"
col	colour of the classification regions
opacity	opacity of classification regions
borders	logical, indicating whether borders should be added to classification regions

### Value

Object of class biplot with the following elements:

### References

Gardner-Lubbe, S., 2016. A triplot for multiclass classification visualisation. *Computational Statistics & Data Analysis*, 94, pp.20-32.

### Examples

```
biplot(iris[,1:4]) |>
classification(predict(MASS::lda(Species ~ ., data = iris))$posterior)
# create a classification biplot
biplot(iris[,1:4]) |>
classification(predict(MASS::lda(Species ~ ., data = iris))$posterior) |>
plot()
```

---

classification.biplot *classification biplot*

---

### Description

Performs calculations for a classification biplot.

### Usage

```
## S3 method for class 'biplot'  
classification(  
  bp,  
  Pmat,  
  dim.biplot = c(2, 1, 3),  
  e.vects = 1:ncol(bp$X),  
  group.aes = NULL,  
  axes = "regression",  
  col = ez.col,  
  opacity = 0.4,  
  borders = FALSE  
)
```

### Arguments

bp	an object of class biplot obtained from preceding function biplot().
Pmat	a matrix containing the posterior probability for the classes
dim.biplot	dimension of the biplot. Only values 1, 2 and 3 are accepted, with default 2.
e.vects	which eigenvectors (principal components) to extract, with default 1:dim.biplot.
group.aes	vector of the same length as the number of rows in the data matrix for differentiated aesthetics for samples.
axes	type of axes, defaults to "regression"
col	colour of the classification regions
opacity	opacity of classification regions
borders	logical, indicating whether borders should be added to classification regions

### Value

an object of class biplot.



---

classify	<i>Classify samples into classes</i>
----------	--------------------------------------

---

**Description**

Classify samples into classes

**Usage**

```
classify(  
  bp,  
  classify.regions = TRUE,  
  col = ez.col,  
  opacity = 0.4,  
  borders = FALSE  
)
```

**Arguments**

bp	an object of class biplot
classify.regions	a logical value indicating whether classifications regions should be shown in the biplot, with default TRUE.
col	the colours of the classification regions
opacity	the opacity levels of the classification regions
borders	the border colours of the classification regions

**Value**

A list object called `classify` appended to the object of class `biplot` with the following elements:

table	the confusion matrix resulting from the classification into classes.
rate	the classification accuracy rate.
classify.regions	a logical value indicating whether classification regions are shown in the biplot.
aes	a list of chosen aesthetics for the colours, opacity levels and border colours of the classification regions.

**Examples**

```
biplot(iris[,1:4],classes = iris[,5]) |> CVA() |> axes(col="black") |>  
  classify(col=c("red","blue","orange"),opacity=0.1) |> plot()
```

CVA

*Perform Canonical Variate Analysis (CVA)***Description**

This function appends the biplot object with elements resulting from performing CVA.

**Usage**

```
CVA(bp, classes=bp$classes, dim.biplot = c(2, 1, 3), e.vects = 1:ncol(bp$X),
     weightedCVA = "weighted", show.class.means = TRUE,
     low.dim = "sample.opt")
```

**Arguments**

<code>bp</code>	an object of class <code>biplot</code> obtained from preceding function <code>biplot()</code> .
<code>classes</code>	a vector of the same length as the number of rows in the data matrix with the class indicator for the samples.
<code>dim.biplot</code>	the dimension of the biplot. Only values 1, 2 and 3 are accepted, with default 2.
<code>e.vects</code>	the vector indicating which eigenvectors (canonical variates) should be plotted in the biplot, with default <code>1:dim.biplot</code> .
<code>weightedCVA</code>	a character string indicating which type of CVA to perform. One of "weighted" (default) for a weighted CVA to be performed (The centring matrix will be a diagonal matrix with the class sizes ( $C = N$ ), "unweightedCent" for unweighted CVA to be performed (The centring matrix is the usual centring matrix ( $C = I_G - G^{-1} \mathbf{1}_G \mathbf{1}'_G$ )) or "unweightedI" for unweighted CVA to be performed while retaining the weighted centroid (The centring matrix is an indicator matrix ( $C = I_G$ )).
<code>show.class.means</code>	a logical value indicating whether to plot the class means on the biplot.
<code>low.dim</code>	a character string indicating which method to use to construct additional dimension(s) if the dimension of the canonical space is smaller than <code>dim.biplot</code> . One of "sample.opt" (default) for maximising the sample predictivity of the individual samples in the biplot or "Bhattacharyya.dist" which is based on the decomposition of the Bhattacharyya distance into a component for the sample means and a component for the dissimilarity between the sample covariance matrices.

**Value**

Object of class `CVA` with the following elements:

<code>X</code>	the matrix of the centered and scaled numeric variables.
<code>Xcat</code>	the data frame of the categorical variables.
<code>raw.X</code>	the original data.

classes	the vector of category levels for the class variable. This is to be used for colour, pch and cex specifications.
na.action	the vector of observations that have been removed.
center	a logical value indicating whether $\mathbf{X}$ is centered.
scaled	a logical value indicating whether $\mathbf{X}$ is scaled.
means	the vector of means for each numerical variable.
sd	the vector of standard deviations for each numerical variable.
n	the number of observations.
p	the number of variables.
group.aes	the vector of category levels for the grouping variable. This is to be used for colour, pch and cex specifications.
g.names	the descriptive names to be used for group labels.
g	the number of groups.
Title	the title of the biplot rendered.
Lmat	the matrix for transformation to the canonical space.
Linv	the inverse of $\mathbf{L}$ .
eigenvalues	the vector of eigenvalues of the two-sided eigenvalue problem.
Z	the matrix with each row containing the details of the points to be plotted (i.e. coordinates).
ax.one.unit	one unit in the positive direction of each biplot axis.
Gmat	the indicator matrix defining membership of the classes.
Xmeans	the matrix of the class means.
Zmeans	the matrix of the class mean coordinates that are plotted in the biplot.
e.vects	the vector indicating which canonical variates are plotted in the biplot.
Cmat	the centring matrix based on different choices of weighting described in arguments.
Bmat	the between class sums of squares and cross products matrix.
Wmat	the within class sums of squares and cross products matrix.
Mrr	the matrix used for prediction from the canonical space (the inverse of $\mathbf{M} = \mathbf{LV}$ ).
Mr	the first $r$ dimensions of the solution to be plotted.
Nmat	the matrix with the class sizes on the diagonal.
lambda.mat	the matrix with the eigenvalues of $\mathbf{W}^{-1/2}\mathbf{B}\mathbf{W}^{-1/2}$ on the diagonal.
class.means	a logical value indicating whether the class means should be plotted in the biplot.
dim.biplot	the dimension of the biplot.
low.dim	the method used to construct additional dimension(s).

### Examples

```
biplot(iris[,1:4]) |> CVA(classes=iris[,5])
# create a CVA biplot
biplot(iris[,1:4]) |> CVA(classes=iris[,5]) |> plot()
```

CVA.biplot

*Calculate elements for the CVA biplot***Description**

This function performs calculations for the construction of a CVA biplot.

**Usage**

```
## S3 method for class 'biplot'
CVA(
  bp,
  classes = bp$classes,
  dim.biplot = c(2, 1, 3),
  e.vects = 1:ncol(bp$X),
  weightedCVA = "weighted",
  show.class.means = TRUE,
  low.dim = "sample.opt"
)
```

**Arguments**

bp	an object of class biplot obtained from preceding function biplot().
classes	a vector of the same length as the number of rows in the data matrix with the class indicator for the samples.
dim.biplot	the dimension of the biplot. Only values 1, 2 and 3 are accepted, with default 2.
e.vects	the vector indicating which eigenvectors (canonical variates) should be plotted in the biplot, with default 1:dim.biplot.
weightedCVA	a character string indicating which type of CVA to perform. One of "weighted" (default) for a weighted CVA to be performed (The centring matrix will be a diagonal matrix with the class sizes ( $\mathbf{C} = \mathbf{N}$ ), "unweightedCent" for unweighted CVA to be performed (The centring matrix is the usual centring matrix ( $\mathbf{C} = \mathbf{I}_G - G^{-1} \mathbf{1}_G \mathbf{1}'_G$ )) or "unweightedI" for unweighted CVA to be performed while retaining the weighted centroid (The centring matrix is an indicator matrix ( $\mathbf{C} = \mathbf{I}_G$ )).
show.class.means	a logical value indicating whether to plot the class means on the biplot.
low.dim	a character string indicating which method to use to construct additional dimension(s) if the dimension of the canonical space is smaller than dim.biplot. One of "sample.opt" (default) for maximising the sample predictivity of the individual samples in the biplot or "Bhattacharyya.dist" which is based on the decomposition of the Bhattacharyya distance into a component for the sample means and a component for the dissimilarity between the sample covariance matrices.

**Value**

an object of class CVA, inherits from class biplot.

**Examples**

```
biplot(iris[,1:4]) |> CVA(classes=iris[,5])
```

---

CVA <code>lowdim</code>	<i>Construct additional dimensions when the dimension of the canonical space is smaller than the dimension of the biplot</i>
-------------------------	--

---

**Description**

This function is used to add dimensions to the CVA biplot when the dimension of the canonical space  $K$  is smaller than the dimension of the biplot (`dim.biplot`). This function is already used in the CVA calculations, and will therefore not have to be used in isolation.

**Usage**

```
CVAlowdim(bp, G, W, Mmat, low.dim, K, e.vects)
```

**Arguments**

<code>bp</code>	an object of class biplot.
<code>G</code>	the indicator matrix defining membership of the classes.
<code>W</code>	the within class sums of squares and cross products matrix.
<code>Mmat</code>	the eigenvector matrix from CVA.
<code>low.dim</code>	a character string indicating which method to use to construct additional dimension(s) if the dimension of the canonical space is smaller than <code>dim.biplot</code> . One of "sample.opt" (default) for maximising the sample predictivity of the individual samples in the biplot or <code>Bhattacharyya.dist</code> which is based on the decomposition of the Bhattacharyya distance into a component for the sample means and a component for the dissimilarity between the sample covariance matrices.
<code>K</code>	the dimension of the canonical space.
<code>e.vects</code>	the vector indicating which canonical variates are plotted in the biplot, with default <code>1:dim.biplot</code>

**Value**

A list with three components:

<code>Mr</code>	the first $r$ dimensions of the solution to be plotted.
<code>Mrr</code>	the matrix used for prediction from the canonical space.
<code>Lmat</code>	the matrix for transformation to the canonical space.

---

density1D	<i>Creates a kernel density in 1-dimension</i>
-----------	--

---

**Description**

Creates a kernel density in 1-dimension

**Usage**

```
density1D(  
  bp,  
  which = NULL,  
  h = "nrd0",  
  kernel = "gaussian",  
  col = ez.col,  
  lwd = 1.5,  
  legend.mar = c(2, 5, 0, 5)  
)
```

**Arguments**

bp	object of class biplot
which	which group.
h	bandwidth.
kernel	character string giving the smoothing kernel to be used.
col	colours to be used for each of the density curves.
lwd	linewidth of density curve.
legend.mar	The margin line of the legend.

**Value**

An object of class biplot.

**Examples**

```
biplot (iris,classes=iris[,5]) |> CVA(dim=1) |> density1D() |> plot()
```

---

`density2D`*Create a density in 2-dimensions*

---

**Description**

Create a density in 2-dimensions

**Usage**

```
density2D(  
  bp,  
  which = NULL,  
  contours = F,  
  h = NULL,  
  n = 100,  
  col = c("green", "yellow", "red"),  
  contour.col = "black",  
  cuts = 50,  
  cex = 0.6,  
  tcl = -0.2,  
  mgp = c(0, -0.25, 0),  
  layout.heights = c(100, 10),  
  legend.mar = c(2, 5, 0, 5)  
)
```

**Arguments**

<code>bp</code>	object of class <code>biplot</code>
<code>which</code>	which group.
<code>contours</code>	logical indicating whether contours are added to the density plot
<code>h</code>	vector of bandwidths for x and y directions, see <a href="#">kde2d</a> .
<code>n</code>	number of grid points in each direction. Can be scalar or a length-2 integer vector.
<code>col</code>	vector of colours to use to form a 'continuous' sequence of colours.
<code>contour.col</code>	colour of the contours.
<code>cuts</code>	number of colours in <code>col</code> .
<code>cex</code>	character expansion.
<code>tcl</code>	The length of tick marks as a fraction of the height of a line of text.
<code>mgp</code>	The margin line.
<code>layout.heights</code>	A vector of values for the heights of rows.
<code>legend.mar</code>	The margin line of the legend.

**Value**

An object of class `biplot`.

**Examples**

```
biplot(iris[,1:4],group.aes = iris[,5]) |> PCA() |>
  density2D(which=3,col=c("white","purple","cyan","blue")) |> plot()
biplot(iris[,1:4],group.aes = iris[,5]) |> PCA() |>
  density2D(which=3,col=c("white","purple","cyan","blue"),contours = TRUE,
  contour.col = "grey") |> plot()
```

---

ellipses

*Concentration ellipses ( $\kappa$ -ellipses)*

---

**Description**

This function produces  $\kappa$ -ellipses, which is a useful geometrical description of the data points about the sample mean.

**Usage**

```
ellipses(bp, df=2, kappa = NULL, which = NULL,
  alpha = 0.95, col = bp$sample$col[which], lty = 1, lwd = 1,
  opacity = 0.25, trace = TRUE)
```

**Arguments**

<code>bp</code>	an object of class <code>biplot</code> .
<code>df</code>	degrees of freedom, with default 2.
<code>kappa</code>	value to construct $\kappa$ -ellipse (the value of $\kappa$ ).
<code>which</code>	the selection of the group for ellipse construction.
<code>alpha</code>	size of $\alpha$ -bag, with default 0.95.
<code>col</code>	colour of ellipse. Multiple $\kappa$ -ellipse for one group will be displayed in the same colour.
<code>lty</code>	line type of ellipse. The same line type will be used per value of $\kappa$ .
<code>lwd</code>	line width of ellipse. The same line width will be used per value of $\kappa$ .
<code>opacity</code>	level of opacity, with default 0.25.
<code>trace</code>	logical, indicating progress of computation.



**Value**

A list with the following components is available:

conc.ellipses	list of coordinates for the $\kappa$ -ellipses for each group.
col	vector of colours for the $\kappa$ -ellipses.
lty	vector of line types for the $\kappa$ -ellipses.
lwd	vector of line widths for the $\kappa$ -ellipses.
alpha	vector of $\alpha$ values.

**References**

Gower, J., Gardner-Lubbe, S. & Le Roux, N. (2011, ISBN: 978-0-470-01255-0) *Understanding Biplots*. Chichester, England: John Wiley & Sons Ltd.

**Examples**

```
biplot (iris[,1:4]) |> PCA(group.aes=iris[,5]) |> ellipses(kappa=2) |> plot()
```

---

extended.matching.coefficient  
*Extended matching coefficient*

---

**Description**

Extended matching coefficient

**Usage**

```
extended.matching.coefficient(X)
```

**Arguments**

X	a data frame containing the categorical variables used for computing the EMC distance
---	---

**Value**

a dist object

**Examples**

```

mtdf <- as.data.frame(mtcars)
mtdf$cyl <- factor(mtdf$cyl)
mtdf$vs <- factor(mtdf$vs)
mtdf$am <- factor(mtdf$am)
mtdf$gear <- factor(mtdf$gear)
mtdf$carb <- factor(mtdf$carb)
extended.matching.coefficient(mtdf[,8:11])

```

---

fit.measures

---

*Compute measures of fit for the biplot.*


---

**Description**

This function computes the measures of fit for the biplot. The biplot object is augmented with additional items, which can differ depending on the type of biplot. The measures provide information on the overall quality of fit and the adequacy of representation of variables.

**Usage**

```
fit.measures(bp)
```

**Arguments**

bp                    an object of class biplot.

**Value**

An object of class biplot. The object is augmented with additional items, depending on the type of biplot object.

quality                the overall quality of fit.  
adequacy                the adequacy of representation of variables.

For an object of class PCA:

axis.predictivity        the fit measure of each individual axis.  
sample.predictivity       the fit measure for each individual sample.

For an object of class CVA:

axis.predictivity        the fit measure of each individual axis.  
class.predictivity        the fit measure for each class mean.

`within.class.axis.predictivity`  
 the fit measure for each axis based on values expressed as deviations from their class means.

`within.class.sample.predictivity`  
 the fit measure for each sample expressed as deviation from its class mean.

### Examples

```
out <- biplot (iris[,1:4]) |> PCA() |> fit.measures()
summary(out)
```

---

interpolate	<i>Interpolate supplementary points and variables to add to the biplot</i>
-------------	--

---

### Description

This function adds supplementary points and variables to the plot from a new data set.

### Usage

```
interpolate(bp, newdata = NULL, newvariable = NULL)
```

### Arguments

<code>bp</code>	an object of class <code>biplot</code> obtained from preceding function <code>biplot()</code> .
<code>newdata</code>	a new data set, similar in structure to the data set supplied to <code>biplot()</code> containing supplementary data points to be added onto the biplot.
<code>newvariable</code>	a new data set, similar in structure to the data set supplied to <code>biplot()</code> containing supplementary variables to be added onto the biplot.

### Value

The object of class `biplot` will be appended with the following elements:

<code>Xnew.raw</code>	the new data.
<code>Xnew</code>	the matrix of the centered and scaled new numeric variables of new data.
<code>Xnew.cat</code>	the matrix of the categorical variables of new data.
<code>Znew</code>	the matrix of the coordinates of the new data in the biplot.

### Examples

```
biplot(data = iris[1:145,]) |> PCA() |> interpolate(newdata = iris[146:150,]) |> plot()
```

---

legend.type	<i>Format the legend for the biplot</i>
-------------	---

---

### Description

This function enables the user to format the legend and make a required selection to display.

### Usage

```
legend.type(bp, samples = FALSE, means = FALSE, bags = FALSE,
            ellipses=FALSE,regions=FALSE, new=FALSE, ...)
```

### Arguments

bp	an object of class biplot.
samples	a logical value indicating whether a legend should be printed for samples, with default FALSE.
means	a logical value indicating whether a legend should be printed for means, with default FALSE.
bags	a logical value indicating whether a legend should be printed for bags, with default FALSE.
ellipses	a logical value indicating whether a legend should be printed for concentration ellipses, with default FALSE.
regions	a logical value indicating whether a legend should be printed for classification regions, with default FALSE.
new	a logical value indicating whether the legend should appear in a new window, with default FALSE.
...	additional arguments to be sent to legend().

### Value

A list with the following components is available:

samples	a logical value indicating whether a legend for samples are provided.
means	a logical value indicating whether a legend for class means are provided.
bags	a logical value indicating whether a legend for $\alpha$ -bags are provided.
ellipses	a logical value indicating whether a legend for $\kappa$ -ellipses are provided.
regions	a logical value indicating whether a legend for classification regions are provided.
new	a logical value indicating whether the legend appears on new plot.

### Examples

```
biplot (iris[,1:4], Title="Test biplot") |> PCA(group.aes = iris[,5]) |>
  legend.type(samples=TRUE) |> plot()
```

---

means *Aesthetics for biplot class / group means*

---

### Description

This function allows formatting changes to class means or group means.

### Usage

```
means (bp, which = NULL, col = NULL, pch = 15, cex = 1, label = FALSE,
label.col = NULL, label.cex = 0.75, label.side = "bottom", label.offset = 0.5,
opacity = 1, shade.darker = TRUE)
```

### Arguments

bp	an object of class biplot.
which	vector of which means to display, with default bp\$g.
col	mean colour, with default to sample colour.
pch	mean plotting character, with default o.
cex	mean character expansion, with default 1.
label	logical, whether means should be labelled or not, with default TRUE.
label.col	vector of length g with the colour of the labels, defaulting to the colour of the means.
label.cex	label text expansion, with default 0.75.
label.side	side of the plotting character where label appears, with default bottom. Note that unlike the argument pos in text(), options are "bottom", "left", "top", "right" and not 1, 2, 3, 4.
label.offset	offset of the label from the mean point. See ?text for a detailed explanation of the argument offset.
opacity	transparency of means.
shade.darker	automatically makes the colour of the means a darker shade than the default (or specified) colour

### Details

The number of classes or groups (defined by group.aes) is indicated as g. If an argument is not of length g, recycling is used.

### Value

A list with the following components is available:

which	which means to display.
col	colour of the means.

pch	plotting character of the means.
cex	expansion of the plotting character of the means.
label	logical, whether means should be labelled.
label.col	colour of the label.
label.cex	expansion of the label.
label.side	side at which to plot the label of means.
label.offset	offset of the label from the mean point.
opacity	transparency of means

### Examples

```
biplot(iris[,1:4]) |> PCA() |>
  means(col = "purple", pch = 15, cex = 2) |> plot()
```

---

newaxes

*Aesthetics for supplementary (new) biplot axes*

---

### Description

Aesthetics for supplementary (new) biplot axes

### Usage

```
newaxes(bp, X.new.names=bp$var.names, which = 1:bp$num.vars, col = "orange", lwd = 1,
  lty = 1, label.dir = "Orthog", label.col = col, label.cex = 0.75, label.line = 0.1,
  ticks = 5, tick.col = col, tick.size = 1, tick.label = TRUE, tick.label.col = tick.col,
  tick.label.cex = 0.6, tick.label.side = "below", predict.col = col, predict.lwd = lwd,
  predict.lty = lty, ax.names = X.new.names, orthogx = 0, orthogy = 0)
```

### Arguments

bp	object of class biplot
X.new.names	refers to the new column names of bp to specify which axes to label.
which	vector of new columns to be displayed in the biplot.
col	vector of size p specifying colours of labels of biplot axes. The default is <code>grey(0.7)</code> .
lwd	axis line width, with default 1.
lty	axis line type, with default 1.
label.dir	One of "Orthog" (default), "Hor" or "Paral" specifying titles of axes to appear orthogonal to the side of the figure; always horizontally or always parallel to the side of the figure.
label.col	axis label colour, with default, col.
label.cex	axis label expansion, with default 0.75.

<code>label.line</code>	axis label written on which margin line, with default 0.1.
<code>ticks</code>	integer-valued vector of size equal to the number of biplot axes to control the number of tickmarks on each individual biplot axis. Default is 5 for each axis.
<code>tick.col</code>	tick mark colour, with default <code>col</code> .
<code>tick.size</code>	positive integer-valued vector with specifying tick mark sizes, with default 1.
<code>tick.label</code>	logical, whether axes should be labelled or not, with default TRUE.
<code>tick.label.col</code>	tick mark label colour, with default <code>tick.col</code> .
<code>tick.label.cex</code>	tick mark label expansion, with default 0.6.
<code>tick.label.side</code>	character vector specifying position of the tick label "below" or "above" the axis.
<code>predict.col</code>	predicted samples colour, with default <code>col</code> .
<code>predict.lwd</code>	predicted samples line width, with default <code>lwd</code> .
<code>predict.lty</code>	predicted samples line type, with default <code>lty</code> .
<code>ax.names</code>	vector of size <code>p</code> containing user defined names for the variables.
<code>orthogx</code>	numeric vector of size <code>p</code> specifying the x-coordinate of the parallel transformation of each axis. Defaults to zero for each axis. Only used when the dimension of the biplot is two.
<code>orthogy</code>	numeric vector of size <code>p</code> specifying the y-coordinate of the parallel transformation of each axis. Defaults to zero for each axis. Only used when the dimension of the biplot is two.

**Value**

an object of class `biplot`

**Examples**

```
biplot(data = iris[,1:2]) |> PCA() |> interpolate(newvariable = iris[3:4]) |>
  newaxes(col="gold") |> plot()
```

---

newsamples

*Aesthetics for supplementary (new) biplot samples*

---

**Description**

This function allows formatting changes to new samples.

**Usage**

```
newsamples (bp, col = "darkorange1", pch = 1, cex = 1, label = FALSE,
  label.name = NULL, label.col = NULL, label.cex = 0.75, label.side = "bottom",
  label.offset = 0.5, connected = FALSE, connect.col = "black", connect.lty=1,
  connect.lwd=1)
```

**Arguments**

<code>bp</code>	an object of class <code>biplot</code> .
<code>col</code>	new sample colour, with default <code>darkorange1</code> .
<code>pch</code>	new sample plotting character, with default <code>o</code> .
<code>cex</code>	new sample character expansion, with default <code>1</code> .
<code>label</code>	logical, whether samples should be labelled or not, with default <code>FALSE</code> .
<code>label.name</code>	names for the new samples
<code>label.col</code>	vector of length number of new samples with the colour of the labels, defaulting to the colour of the sample points.
<code>label.cex</code>	label text expansion, with default <code>0.75</code> .
<code>label.side</code>	side of the plotting character where label appears, with default <code>bottom</code> . Note that unlike the argument <code>pos</code> in <code>text()</code> , options are "bottom", "left", "top", "right" and not 1, 2, 3, 4.
<code>label.offset</code>	offset of the label from the data point. See <code>?text</code> for a detailed explanation of the argument <code>offset</code> .
<code>connected</code>	logical, whether samples are connected in order of rows of data matrix, with default <code>FALSE</code> .
<code>connect.col</code>	colour of the connecting line, with default <code>black</code> .
<code>connect.lty</code>	line type of the connecting line, with default <code>1</code> .
<code>connect.lwd</code>	line width of the connecting line, with default <code>1</code> .

**Value**

A list with the following components is available:

<code>col</code>	colour of the samples.
<code>pch</code>	plotting character of the samples.
<code>cex</code>	expansion of the plotting character of the samples.
<code>label</code>	<code>TRUE</code> or <code>FALSE</code> , whether samples should be labelled.
<code>label.col</code>	colour of the label.
<code>label.cex</code>	expansion of the label.
<code>label.side</code>	side at which to plot the label of samples.
<code>label.offset</code>	offset of the label from the data point.
<code>connected</code>	<code>TRUE</code> or <code>FALSE</code> , whether samples should be connected in row order of <code>X</code> .
<code>connect.col</code>	colour of the connecting line.
<code>connect.lty</code>	line type of the connecting line.
<code>connect.lwd</code>	line width of the connecting line.

**Examples**

```
biplot(data = iris[1:145,]) |> PCA() |> samples(col = "grey") |>
interpolate(newdata = iris[146:150,]) |> newsamples(col = rainbow(6), pch=15) |> plot()
```



**Description**

This function appends the biplot object with elements resulting from performing PCA.

**Usage**

```
PCA(bp, dim.biplot = c(2, 1, 3), e.vects = 1:ncol(bp$X),
    group.aes = NULL, show.class.means = FALSE, correlation.biplot = FALSE)
```

**Arguments**

<code>bp</code>	an object of class <code>biplot</code> obtained from preceding function <code>biplot()</code> .
<code>dim.biplot</code>	the dimension of the biplot. Only values 1, 2 and 3 are accepted, with default 2.
<code>e.vects</code>	the vector indicating which eigenvectors (principal components) should be plotted in the biplot, with default <code>1:dim.biplot</code> .
<code>group.aes</code>	a vector of the same length as the number of rows in the data matrix for differentiated aesthetics for samples.
<code>show.class.means</code>	a logical value indicating whether group means should be plotted in the biplot.
<code>correlation.biplot</code>	a logical value. If <code>FALSE</code> , the distances between sample points are optimally approximated in the biplot. If <code>TRUE</code> , the correlations between variables are optimally approximated by the cosine of the angles between axes. Default is <code>FALSE</code> .

**Value**

An object of class `PCA` with the following elements:

<code>X</code>	the matrix of the centered and scaled numeric variables.
<code>Xcat</code>	the data frame of the categorical variables.
<code>raw.X</code>	the original data.
<code>classes</code>	the vector of category levels for the class variable. This is to be used for colour, pch and cex specifications.
<code>na.action</code>	the vector of observations that have been removed.
<code>center</code>	a logical value indicating whether $\mathbf{X}$ is centered.
<code>scaled</code>	a logical value indicating whether $\mathbf{X}$ is scaled.
<code>means</code>	the vector of means for each numerical variable.
<code>sd</code>	the vector of standard deviations for each numerical variable.
<code>n</code>	the number of observations.
<code>p</code>	the number of variables.

group.aes	the vector of category levels for the grouping variable. This is to be used for colour, pch and cex specification.
g.names	the descriptive names to be used for group labels.
g	the number of groups.
Title	the title of the biplot rendered.
Z	the matrix with each row containing the details of the points that are plotted (i.e. coordinates).
Lmat	the matrix for transformation to the principal components.
Linv	the inverse of $\mathbf{L}$ .
eigenvalues	the vector of eigenvalues of the covariance matrix of $\mathbf{X}$ .
ax.one.unit	one unit in the positive direction of each biplot axis.
e.vects	the vector indicating which principal components are plotted in the biplot.
Vr	the $1:\text{dim.biplot}$ columns of $\mathbf{V}$ .
dim.biplot	the dimension of the biplot.
V.mat	the matrix containing the right singular vectors of $\mathbf{X}$ .
Sigma.mat	the matrix with the singular values of $\mathbf{X}$ on the diagonal.
U.mat	the matrix containing the left singular vectors of $\mathbf{X}$ .
class.means	a logical value indicating whether group means are plotted in the biplot.
Zmeans	the matrix of class mean coordinates that are plotted in the biplot.

## References

Gabriel, K.R. (1971) The biplot graphic display of matrices with application to principal component analysis. *Biometrika*. 58(3):453–467.

## Examples

```
biplot(iris[,1:4]) |> PCA()
# create a PCA biplot
biplot(data = iris) |> PCA() |> plot()
```

---

PCA.biplot

*Calculate elements for the PCA biplot*

---

## Description

This function performs calculations for the construction of a PCA biplot.

**Usage**

```
## S3 method for class 'biplot'
PCA(
  bp,
  dim.biplot = c(2, 1, 3),
  e.vects = 1:ncol(bp$X),
  group.aes = NULL,
  show.class.means = FALSE,
  correlation.biplot = FALSE
)
```

**Arguments**

`bp` an object of class `biplot` obtained from preceding function `biplot()`.

`dim.biplot` the dimension of the biplot. Only values 1, 2 and 3 are accepted, with default 2.

`e.vects` the vector indicating which eigenvectors (principal components) should be plotted in the biplot, with default `1:dim.biplot`.

`group.aes` a vector of the same length as the number of rows in the data matrix for differentiated aesthetics for samples.

`show.class.means` a logical value indicating whether group means should be plotted in the biplot.

`correlation.biplot` a logical value. If `FALSE`, the distances between sample points are optimally approximated in the biplot. If `TRUE`, the correlations between variables are optimally approximated by the cosine of the angles between axes. Default is `FALSE`.

**Value**

an object of class `PCA`, inherits from class `biplot`.

**Examples**

```
biplot(iris[,1:4]) |> PCA()
# create a PCA biplot
biplot(data = iris) |> PCA() |> plot()
```

**Description**

Principal Coordinate Analysis (PCO) biplot method

**Usage**

```
PCO(bp, Dmat=NULL, dist.func=NULL, dist.func.cat=NULL,
     dim.biplot = c(2,1,3), e.vects = NULL, group.aes=NULL,
     show.class.means = FALSE, axes = c("regression","splines"), ...)
```

**Arguments**

<code>bp</code>	an object of class <code>biplot</code> obtained from preceding function <code>biplot()</code> .
<code>Dmat</code>	$n \times n$ matrix of Euclidean embeddable distances between samples
<code>dist.func</code>	function to compute Euclidean embeddable distances between samples. The default <code>NULL</code> computes Euclidean distance.
<code>dist.func.cat</code>	function to compute Euclidean embeddable distance between categorical variables for the samples. The default <code>NULL</code> computes the extended matching coefficient.
<code>dim.biplot</code>	dimension of the biplot. Only values 1, 2 and 3 are accepted, with default 2.
<code>e.vects</code>	<code>e.vects</code> which eigenvectors (canonical variates) to extract, with default <code>1:dim.biplot</code> .
<code>group.aes</code>	vector of the same length as the number of rows in the data matrix for differentiated aesthetics for samples.
<code>show.class.means</code>	logical, indicating whether to plot the class means on the biplot.
<code>axes</code>	type of biplot axes, currently only regression axes are implemented
<code>...</code>	more arguments to <code>dist.func</code>

**Value**

Object of class `biplot`

**Examples**

```
biplot(iris[,1:4]) |> PCO(dist.func = sqrtManhattan)
# create a CVA biplot
biplot(iris[,1:4]) |> PCO(dist.func = sqrtManhattan) |> plot()
```

---

PCO.biplot

*PCO biplot*


---

**Description**

Computes Principal Coordinate Analysis biplot

**Usage**

```
## S3 method for class 'biplot'
PCO(
  bp,
  Dmat = NULL,
  dist.func = NULL,
  dist.func.cat = NULL,
  dim.biplot = c(2, 1, 3),
  e.vects = NULL,
  group.aes = NULL,
  show.class.means = FALSE,
  axes = c("regression", "splines"),
  ...
)
```

**Arguments**

<code>bp</code>	an object of class <code>biplot</code> obtained from preceding function <code>biplot()</code> .
<code>Dmat</code>	$n \times n$ matrix of Euclidean embeddable distances between samples
<code>dist.func</code>	function to compute Euclidean embeddable distances between samples. The default <code>NULL</code> computes Euclidean distance.
<code>dist.func.cat</code>	function to compute Euclidean embeddable distance between categorical variables for the samples. The default <code>NULL</code> computes the extended matching coefficient.
<code>dim.biplot</code>	dimension of the biplot. Only values 1, 2 and 3 are accepted, with default 2.
<code>e.vects</code>	<code>e.vects</code> which eigenvectors (canonical variates) to extract, with default <code>1:dim.biplot</code> .
<code>group.aes</code>	vector of the same length as the number of rows in the data matrix for differentiated aesthetics for samples.
<code>show.class.means</code>	logical, indicating whether to plot the class means on the biplot.
<code>axes</code>	type of biplot axes, currently only regression axes are implemented
<code>...</code>	more arguments to <code>dist.func</code>

**Value**

an object of class `biplot`.

**Examples**

```
biplot(iris) |> PCO(dist.func=sqrtManhattan) |> plot()
```

---

plot.biplot

*Generic Plotting function of objects of class biplot*


---

**Description**

Generic Plotting function of objects of class biplot

**Usage**

```
## S3 method for class 'biplot'
plot(
  x,
  exp.factor = 1.2,
  axis.predictivity = NULL,
  sample.predictivity = NULL,
  zoom = FALSE,
  xlim = NULL,
  ylim = NULL,
  ...
)
```

**Arguments**

x	An object of class biplot.
exp.factor	numeric value with default axes of the biplot. Larger values for zooming out and smaller values for zooming in with respect to sample points in the biplot display.
axis.predictivity	either logical or a numeric value between 0 and 1. If it is a numeric value, this value is used as threshold so that only axes with axis predictivity larger than the threshold is displayed. If axis.predictivity = TRUE, the axis color is 'diluted' in proportion with the axis predictivity.
sample.predictivity	either a logical or a numeric value between 0 and 1. If it is a numeric value, this value is used as threshold so that only samples with sample predictivity larger than the threshold is displayed. if sample.predictivity = TRUE, the sample size is shrunked in proportion with the sample predictivity.
zoom	logical, allowing the user to select an area to zoom into
xlim	horisontal limits of the plot
ylim	vertical limits of the plot
...	additional arguments.

**Value**

An object of class biplot.

**Examples**

```
biplot (iris[,1:4]) |> PCA() |> plot()
```

---

plot3D	<i>Generic Plotting function of objects of class biplot in three dimensions</i>
--------	---

---

**Description**

Generic Plotting function of objects of class biplot in three dimensions

**Usage**

```
plot3D(bp, exp.factor = 1.2, ...)
```

**Arguments**

bp	an object of class biplot
exp.factor	factor to expand plotting area beyond samples.
...	more arguments

**Value**

an object of class biplot

**Examples**

```
biplot(data = iris) |> PCA(dim.biplot = 3) |> plot3D()
```

---

prediction	<i>Predict samples to display on the biplot</i>
------------	---

---

**Description**

This function makes predictions of sample points, variables and means and displays them on the biplot.

**Usage**

```
prediction(bp, predict.samples = NULL, predict.means = NULL, which = 1:bp$p)
```

**Arguments**

bp	an object of class biplot obtained from preceding function biplot().
predict.samples	a vector specifying which samples to predict.
predict.means	a vector specifying which group means to predict.
which	a vector specifying which variable to do the prediction.

**Value**

A list object called `predict` appended to the object of class `biplot` with the following elements:

<code>samples</code>	a vector of indices of samples which are being predicted.
<code>predict.means</code>	a vector of group names of groups for which the means are being predicted.
<code>which</code>	the vector of indices variables which are being predicted.
<code>predict.mat</code>	the matrix of predicted samples.
<code>predict.means.mat</code>	the matrix of predicted group means.

**Examples**

```
biplot(data = iris[,1:4]) |> PCA(group.aes=iris[,5], show.class.means = TRUE) |>
prediction(141:145,1:3) |> plot()
```

---

<code>print.biplot</code>	<i>Generic print function for objects of class biplot</i>
---------------------------	---

---

**Description**

This function is used to print output when the `biplot` object is created.

**Usage**

```
## S3 method for class 'biplot'
print(x, ...)
```

**Arguments**

<code>x</code>	an object of class <code>biplot</code> .
<code>...</code>	additional arguments.

**Value**

This function will not produce a return value, it is called for side effects.

**Examples**

```
out <- biplot (iris[,1:4]) |> PCA()
out
```



---

print.CA	<i>Generic print function of objects of class CA</i>
----------	--

---

**Description**

Generic print function of objects of class CA

**Usage**

```
## S3 method for class 'CA'
print(x, ...)
```

**Arguments**

x	an object of class CA
...	additional arguments

**Value**

no return value, called for side effects

**Examples**

```
out <- biplot(HairEyeColor[, , 1], center=FALSE) |> CA()
out
```

---

reflect	<i>Reflect the biplot about a chosen axis</i>
---------	---

---

**Description**

This function provides the user with an option to reflect the biplot horizontally, vertically or diagonally.

**Usage**

```
reflect(bp, reflect.axis = c("FALSE", "x", "y", "xy"))
```

**Arguments**

bp	an object of class biplot
reflect.axis	a character string indicating which axis about to reflect. One of FALSE (default), "x" for reflection about the x-axis, "y" for reflection about the y-axis and "xy" for reflection about both axes.

**Value**

An object of class `biplot`

**Examples**

```
biplot(iris[,1:4],group.aes = iris[,5]) |> PCA() |> reflect("x") |> plot()
biplot(iris[,1:4],group.aes = iris[,5]) |> PCA() |> reflect("y") |> plot()
biplot(iris[,1:4],group.aes = iris[,5]) |> PCA() |> reflect("xy") |> plot()
```

---

regress

*Regression biplot method*

---

**Description**

Regression biplot method

**Usage**

```
regress(bp, Z, group.aes=NULL, show.group.means = TRUE,
        axes = c("regression", "splines"))
```

**Arguments**

`bp` an object of class `biplot` obtained from preceding function `biplot()`.

`Z` the matrix of coordinates of the samples

`group.aes` vector of the same length as the number of rows in the data matrix for differentiated aesthetics for samples.

`show.group.means` logical, indicating whether group means should be plotted in the biplot.

`axes` the type of axes to be fitted to the biplot. Options are 'regression' for linear regression axes (default) and 'splines' for B-spline axes.

**Value**

Object of class `biplot`

**Examples**

```
biplot(iris[,1:4]) |> regress(Z=cmdscale(dist(iris[,1:4]))) |> plot()
```

---

regress.biplot	<i>Regression biplot</i>
----------------	--------------------------

---

### Description

Computes regression biplot axes

### Usage

```
## S3 method for class 'biplot'  
regress(  
  bp,  
  Z,  
  group.aes = NULL,  
  show.group.means = TRUE,  
  axes = c("regression", "splines")  
)
```

### Arguments

**bp** an object of class `biplot` obtained from preceding function `biplot()`.

**Z** the matrix of coordinates of the samples

**group.aes** vector of the same length as the number of rows in the data matrix for differentiated aesthetics for samples.

**show.group.means** logical, indicating whether group means should be plotted in the biplot.

**axes** the type of axes to be fitted to the biplot. Options are 'regression' for linear regression axes (default) and 'splines' for B-spline axes.

### Value

an object of class `biplot`.

### Examples

```
biplot(iris) |> regress(Z = cmdscale(dist(iris[,1:4]))) |> plot()
```

---

rotate	<i>Rotate the biplot a chosen amount of degrees</i>
--------	---

---

### Description

This function provides the user with an option to rotate the biplot anti-clockwise or clockwise.

### Usage

```
rotate(bp, rotate.degrees = 0)
```

### Arguments

bp	an object of class biplot
rotate.degrees	a value specifying the degrees the biplot should be rotated, with default 0. A positive value results in anti-clockwise rotation and a negative value in clockwise rotation.

### Value

An object of class biplot.

### Examples

```
biplot(iris[,1:4],group.aes = iris[,5]) |> PCA() |> rotate(200) |> plot()
```

---

samples	<i>Aesthetics for biplot samples</i>
---------	--------------------------------------

---

### Description

This function allows formatting changes to samples.

### Usage

```
samples (bp, which = 1:bp$g, col = ez.col, pch = 16, cex = 1,
label = FALSE, label.name = NULL, label.col=NULL, label.cex = 0.75,
label.side = "bottom", label.offset = 0.5,
connected=FALSE, connect.col = "black", connect.lty = 1,
connect.lwd = 1, opacity = 1)
```

**Arguments**

<code>bp</code>	an object of class <code>biplot</code> .
<code>which</code>	vector of which groups of samples to display, with default <code>bp\$g</code> .
<code>col</code>	sample colour, with default <code>blue</code> .
<code>pch</code>	sample plotting character, with default <code>+</code> .
<code>cex</code>	sample character expansion, with default <code>1</code> .
<code>label</code>	logical ( <code>TRUE</code> , <code>FALSE</code> ), whether samples should be labelled, with default <code>FALSE</code> . Alternatively, specify <code>"ggrepel"</code> for non-overlapping placement of labels.
<code>label.name</code>	vector of length number of samples, with default <code>NULL</code> , <code>rownames(bp)</code> are used.
<code>label.col</code>	vector of length number of samples with the colour of the labels, defaulting to the colour of the sample points.
<code>label.cex</code>	label text expansion, with default <code>0.75</code> .
<code>label.side</code>	side of the plotting character where label appears, with default <code>bottom</code> . Note that unlike the argument <code>pos</code> in <code>text()</code> , options are <code>"bottom"</code> , <code>"left"</code> , <code>"top"</code> , <code>"right"</code> and not <code>1</code> , <code>2</code> , <code>3</code> , <code>4</code> .
<code>label.offset</code>	offset of the label from the data point. See <code>?text</code> for a detailed explanation of the argument <code>offset</code> .
<code>connected</code>	logical, whether samples are connected in order of rows of data matrix, with default <code>FALSE</code> .
<code>connect.col</code>	colour of the connecting line, with default <code>black</code> .
<code>connect.lty</code>	line type of the connecting line, with default <code>1</code> .
<code>connect.lwd</code>	line width of the connecting line, with default <code>1</code> .
<code>opacity</code>	opacity of sample points, with default <code>1</code> (opaque).

**Details**

The arguments `which`, `col`, `pch` and `cex` are based on the specification of `group.aes` or `classes`. If no groups are specified, a single colour, plotting character and / or character expansion is expected. If `g` groups are specified, vectors of length `g` is expected, or values are recycled to length `g`.

The arguments `label`, `label.cex`, `label.side` and `label.offset` are based on the sample size `n`. A single value will be recycled `n` times or a vector of length `n` is expected.

**Value**

A list with the following components is available:

<code>which</code>	which means to display.
<code>col</code>	colour of the samples.
<code>pch</code>	plotting character of the samples.
<code>cex</code>	expansion of the plotting character of the samples.
<code>label</code>	<code>TRUE</code> or <code>FALSE</code> , whether samples should be labelled, with default <code>FALSE</code> .
<code>label.name</code>	If <code>NULL</code> , the row names will be used, with default <code>NULL</code> . Alternatively, a vector of length <code>n</code> should be used.

label.col	colour of the label.
label.cex	expansion of the label.
label.side	side at which to plot the label of samples.
label.offset	offset of the label from the data point.
connected	TRUE or FALSE, whether samples should be connected in row order of X.
connect.col	colour of the connecting line.
connect.lty	line type of the connecting line.
connect.lwd	line width of the connecting line.
opacity	opacity of sample points, with default 1 (opaque).

### Examples

```

biplot(iris[,1:4]) |> PCA() |> samples(col="purple",pch=15, opacity=0.5) |> plot()
biplot(iris[,1:4]) |> PCA() |>
  samples(col="purple",pch=NA, opacity=0.5, label = TRUE) |> plot()
biplot(iris[,1:4]) |> PCA() |>
  samples(col="purple",pch=NA, opacity=0.5, label = TRUE,
    label.name = paste("s:",1:150, sep="")) |>
  plot()
biplot(iris[,1:4]) |> PCA() |>
  samples(col="purple",pch=NA, opacity=0.5, label = "ggrepel") |> plot()

```

---

sqrtManhattan	<i>Computes the square root of the Manhattan distance An example of a Euclidean embeddable distance metric</i>
---------------	--

---

### Description

Computes the square root of the Manhattan distance An example of a Euclidean embeddable distance metric

### Usage

```
sqrtManhattan(X)
```

### Arguments

X	matrix of samples x variables for computation of samples x samples distance matrix
---	--

### Value

a dist object

### Examples

```
sqrtManhattan(iris[,1:4])
```

---

summary.biplot	<i>Generic summary function for objects of class biplot</i>
----------------	---

---

### Description

This function is used to print summary output of the biplot. These summary outputs are related to measures of fit.

### Usage

```
## S3 method for class 'biplot'  
summary(  
  object,  
  adequacy = TRUE,  
  axis.predictivity = TRUE,  
  sample.predictivity = TRUE,  
  class.predictivity = TRUE,  
  within.class.axis.predictivity = TRUE,  
  within.class.sample.predictivity = TRUE,  
  ...  
)
```

### Arguments

object	an object of class biplot.
adequacy	a logical value indicating whether variable adequacies should be reported, with default TRUE.
axis.predictivity	a logical value indicating whether axis predictivities should be reported, with default TRUE.
sample.predictivity	a logical value indicating whether sample predictivities should be reported, with default TRUE.
class.predictivity	a logical value indicating whether class predictivities should be reported, with default TRUE (only applicable to objects of class CVA).
within.class.axis.predictivity	a logical value indicating whether within class axis predictivity should be reported, with default TRUE (only applicable to objects of class CVA).
within.class.sample.predictivity	a logical value indicating whether within class sample predictivity should be reported, with default TRUE (only applicable to objects of class CVA).
...	additional arguments.

### Value

This function will not produce a return value, it is called for side effects.

**Examples**

```
out <- biplot(iris[,1:4]) |> PCA() |> fit.measures()
summary(out)
```

---

translate_axes	<i>Translate biplot axes</i>
----------------	------------------------------

---

**Description**

Automatically or manually translate the axes away from the center of the plot

**Usage**

```
translate_axes(bp, delta = 0, swop = FALSE, distances = NULL)
```

**Arguments**

bp	An object of class biplot
delta	numeric value indicating distance between axes
swop	logical. Change the direction in which axes are translated
distances	numeric vector of distances. Used to manually parallel translate the axes.

**Details**

This function uses the same algorithm implemented in [TDAbiplot](#) in the `bip15` package. It translates the axes out of the center of the plot. Correlated axes generally gets translated in the same direction.

This function calculates the orthogx and orthogy paramaters in [axes\(\)](#)

**Value**

An object of class biplot with the translated distances appended under `bp$axes`

**Examples**

```
#Translate the axes out of the plot center

bp <- biplot(state.x77,scaled = TRUE)|>
  CVA(state.region) |>
  translate_axes(swop=TRUE,delta =0.2)|>
  plot(exp.factor=3)

#adjust the distance of an axis

dist <- bp$axes$translate_distance
dist[7] <- 0.4
bp |> translate_axes(delta = 0.2, distances=dist) |> plot()
```



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