

# Package ‘fido’

May 30, 2024

**Type** Package

**Title** Bayesian Multinomial Logistic Normal Regression

**Version** 1.1.0

**Date** 2024-05-15

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**Description** Provides methods for fitting and inspection of Bayesian Multinomial Logistic Normal Models using MAP estimation and Laplace Approximation as developed in Silverman et. Al. (2022) <<https://www.jmlr.org/papers/v23/19-882.html>>. Key functionality is implemented in C++ for scalability. 'fido' replaces the previous package 'stray'.

**License** GPL-3

**URL** <https://jsilve24.github.io/fido/>

**Depends** R (>= 4.1.0)

**Imports** Rcpp (>= 0.12.17), dplyr, ggplot2, purrr, tidybayes, rlang, tidy

**LinkingTo** Rcpp, RcppEigen, RcppNumerical, RcppZiggurat, BH

**RoxygenNote** 7.3.1

**Suggests** testthat (>= 2.1.0), knitr, rmarkdown, ape, numDeriv, LaplacesDemon, MCMCpack, phyloseq

**VignetteBuilder** knitr

**LazyData** true

**BugReports** <https://github.com/jsilve24/fido/issues>

**Encoding** UTF-8

**NeedsCompilation** yes

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**Repository** CRAN

**Date/Publication** 2024-05-30 07:00:24 UTC

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**alr***Compute the ALR of a matrix*

---

**Description**

Compute the ALR of a matrix

**Usage**

alr(x, d = NULL)

**Arguments**

x                    A matrix where the rows are the samples  
 d                    Index of column used as a reference. Defaults to last column

**Value**

matrix

---

alrInv                    *Compute the inverse ALR of a matrix*

---

**Description**

Compute the inverse ALR of a matrix

**Usage**

```
alrInv(y, d = NULL)
```

**Arguments**

y                    An ALR transformed matrix  
 d                    Index of column used as a reference. Defaults to last column

**Value**

matrix

---

alrInv\_array                    *Compute the ALR of an array*

---

**Description**

Compute the ALR of an array

**Usage**

```
alrInv_array(y, d = dim(y)[coords] + 1, coords)
```

**Arguments**

y                    multidimensional ALR transformed array  
 d                    Index of column used as a reference. Defaults to last column  
 coords                index of dimension of 'x' that represents coordinates

**Value**

array

---

alr_array	<i>Compute the ALR of an array</i>
-----------	------------------------------------

---

**Description**

Compute the ALR of an array

**Usage**

```
alr_array(x, d = dim(x)[parts], parts)
```

**Arguments**

x	multidimensional array in simplex
d	Index of column used as a reference. Defaults to last column
parts	index of dimension of 'x' that represents parts

**Value**

array

---

as.list.orthusfit	<i>Convert object of class orthusfit to a list</i>
-------------------	--

---

**Description**

Convert object of class orthusfit to a list

**Usage**

```
## S3 method for class 'orthusfit'  
as.list(x, ...)
```

**Arguments**

x	an object of class orthusfit
...	currently unused

**Value**

A list of the converted orthusfit object

as.list.pibblefit      *Convert object of class pibblefit to a list*

---

**Description**

Convert object of class pibblefit to a list

**Usage**

```
## S3 method for class 'pibblefit'  
as.list(x, ...)
```

**Arguments**

x                    an object of class pibblefit  
...                   currently unused

**Value**

A list from the converted pibblefit object.

---

as.orthusfit            *convert list to orthusfit*

---

**Description**

convert list to orthusfit

**Usage**

```
as.orthusfit(object)
```

**Arguments**

object                list object

**Value**

An orthusfit object

---

as.pibblefit	<i>convert list to pibblefit</i>
--------------	----------------------------------

---

**Description**

convert list to pibblefit

**Usage**

```
as.pibblefit(object)
```

**Arguments**

object            list object

**Value**

A pibblefit object

---

basset_fit	<i>Interface to fit basset models</i>
------------	---------------------------------------

---

**Description**

Basset (A Lazy Learner) - non-linear regression models in fido

**Usage**

```
basset(  
  Y = NULL,  
  X,  
  epsilon = NULL,  
  Theta = NULL,  
  Gamma = NULL,  
  Xi = NULL,  
  linear = NULL,  
  init = NULL,  
  pars = c("Eta", "Lambda", "Sigma"),  
  newdata = NULL,  
  ...  
)  
  
## S3 method for class 'bassetfit'  
refit(m, pars = c("Eta", "Lambda", "Sigma"), ...)
```

**Arguments**

Y	D x N matrix of counts (if NULL uses priors only)
X	Q x N matrix of covariates (cannot be NULL)
upsilon	dof for inverse wishart prior (numeric must be > D) (default: D+3)
Theta	A function from dimensions dim(X) -> (D-1)xN (prior mean of gaussian process). For an additive GP model, can be a list of functions from dimensions dim(X) -> (D-1)xN + a (optional) matrix of size (D-1)xQ for the prior of a linear component if desired.
Gamma	A function from dimension dim(X) -> NxN (kernel matrix of gaussian process). For an additive GP model, can be a list of functions from dimension dim(X) -> NxN + a QxQ prior covariance matrix if a linear component is specified. It is assumed that the order matches the order of Theta.
xi	(D-1)x(D-1) prior covariance matrix (default: ALR transform of diag(1)*(upsilon-D)/2 - this is essentially iid on "base scale" using Aitchison terminology)
linear	A vector denoting which rows of X should be used if a linear component is specified. Default is all rows.
init	(D-1) x Q initialization for Eta for optimization
pars	character vector of posterior parameters to return
newdata	Default is NULL. If non-null, newdata is used in the uncollapse sampler in place of X.
...	other arguments passed to <a href="#">pibble</a> (which is used internally to fit the basset model)
m	object of class bassetfit

**Details**

the full model is given by:

$$\begin{aligned}
 Y_j &\sim \text{Multinomial}(\pi_j) \\
 \pi_j &= \Phi^{-1}(\eta_j) \\
 \eta &\sim MN_{D-1 \times N}(\Lambda, \Sigma, I_N) \\
 \Lambda &\sim GP_{D-1 \times Q}(\Theta(X), \Sigma, \Gamma(X)) \\
 \Sigma &\sim \text{InvWish}(v, \Xi)
 \end{aligned}$$

Where  $\Gamma(X)$  is short hand for the Gram matrix of the Kernel function.

Alternatively can be used to fit an additive GP of the form:

$$\begin{aligned}
 Y_j &\sim \text{Multinomial}(\pi_j) \\
 \pi_j &= \Phi^{-1}(\eta_j) \\
 \eta &\sim MN_{D-1 \times N}(\Lambda, \Sigma, I_N) \\
 \Lambda &= \Lambda_1 + \dots + \Lambda_p + BX \\
 \Lambda_1 &\sim GP_{D-1 \times Q}(\Theta_1(X), \Sigma, \Gamma_1(X))
 \end{aligned}$$

...

$$\Lambda_p \sim GPD_{D-1 \times Q}(\Theta_p(X), \Sigma, \Gamma_p(X))$$

$$B \sim MN(\Theta_B, \Sigma, \Gamma_B)$$

$$\Sigma \sim InvWish(v, \Xi)$$

Where  $\Gamma(X)$  is short hand for the Gram matrix of the Kernel function.

Default behavior is to use MAP estimate for uncollapsing the LTP model if laplace approximation is not preformed.

### Value

an object of class bassetfit

---

check_dims	<i>Check vector/matrix/data.frame for expected dimensions or throw error</i>
------------	--

---

### Description

Check vector/matrix/data.frame for expected dimensions or throw error

### Usage

```
check_dims(x, d, par)
```

### Arguments

x	object to check
d	expected dimensions
par	character name of x (for error message)

### Value

nothing if no error, otherwise throws error

### Examples

```
y <- c(1,3,4)
check_dims(y, 3, "y")
```

---

clr_array	<i>Compute the CLR of an array</i>
-----------	------------------------------------

---

**Description**

Compute the CLR of an array

**Usage**

```
clr_array(x, parts)
```

**Arguments**

x	multidimensional array in index
parts	index of dimension of 'x' that represents parts

**Value**

array

---

coef.orthusfit	<i>Return regression coefficients of orthus object</i>
----------------	--

---

**Description**

Orthus: Returned as array of dimension  $(D-1+P) \times Q \times \text{iter}$  (if in ALR or ILR) otherwise  $(D+P) \times Q \times \text{iter}$ .

**Usage**

```
## S3 method for class 'orthusfit'
coef(object, ...)
```

**Arguments**

object	an object of class orthusfit
...	other options passed to coef.orthusfit (see details)

**Details**

Other arguments:

- use\_names if column and row names were passed for Y and X in call to [pibble](#), should these names be applied to output array.

**Value**

Array of dimension  $(D-1) \times Q \times \text{iter}$

---

coef.pibblefit	<i>Return regression coefficients of pibblefit object</i>
----------------	---

---

### Description

Pibble: Returned as array of dimension  $(D-1) \times Q \times \text{iter}$  (if in ALR or ILR) otherwise  $D \times Q \times \text{iter}$  (if in proportions or clr).

### Usage

```
## S3 method for class 'pibblefit'
coef(object, ...)
```

### Arguments

object	an object of class pibblefit
...	other options passed to coef.pibblefit (see details)

### Details

Other arguments:

- ‘use\_names’ if column and row names were passed for Y and X in call to `pibble`, should these names be applied to output array.

### Value

Array of dimension  $(D-1) \times Q \times \text{iter}$

---

conjugateLinearModel	<i>Solve Bayesian Multivariate Conjugate Linear Model</i>
----------------------	---

---

### Description

See details for model. Notation: N is number of samples, D is the dimension of the response, Q is number of covariates.

### Usage

```
conjugateLinearModel(Y, X, Theta, Gamma, Xi, epsilon, n_samples = 2000L)
```

**Arguments**

Y	matrix of dimension D x N
X	matrix of covariates of dimension Q x N
Theta	matrix of prior mean of dimension D x Q
Gamma	covariance matrix of dimension Q x Q
Xi	covariance matrix of dimension D x D
upsilon	scalar (must be > D-1) degrees of freedom for InvWishart prior
n_samples	number of samples to draw (default: 2000)

**Details**

$$Y \sim MN_{D-1 \times N}(\Lambda \mathbf{X}, \Sigma, I_N)$$

$$\Lambda \sim MN_{D-1 \times Q}(\Theta, \Sigma, \Gamma)$$

$$\Sigma \sim InvWish(v, \Xi)$$

This function provides a means of sampling from the posterior distribution of Lambda and Sigma.

**Value**

List with components

1. Lambda Array of dimension (D-1) x Q x n\_samples (posterior samples)
2. Sigma Array of dimension (D-1) x (D-1) x n\_samples (posterior samples)

**Examples**

```
sim <- pibble_sim()
eta.hat <- t(alr(t(sim$Y+0.65)))
fit <- conjugateLinearModel(eta.hat, sim$X, sim$Theta, sim$Gamma,
                           sim$Xi, sim$upsilon, n_samples=2000)
```

---

convert\_orthus\_covariance

*Convert orthus covariance matrices between representations*

---

**Description**

Convert orthus covariance matrices between representations

**Usage**

```
oilrvar2ilrvar(Sigma, s, V1, V2)
```

```
oilrvar2clrvar(Sigma, s, V)
```

```
oclrvar2ilrvar(Sigma, s, V)
```

```
oalrvar2clrvar(Sigma, s, d1)
```

```
oclrvar2alrvar(Sigma, s, d2)
```

```
oalrvar2alrvar(Sigma, s, d1, d2)
```

```
oalrvar2ilrvar(Sigma, s, d1, V2)
```

```
oilrvar2alrvar(Sigma, s, V1, d2)
```

**Arguments**

Sigma	covariance matrix array in specified transformed space ( $\dim(\text{Sigma})[3]=\text{iter}$ )
s	first s rows and columns of Sigma are transformed
V1	ILR contrast matrix of basis Sigma is already in
V2	ILR contrast matrix of basis Sigma is desired in
V	ILR contrast matrix (i.e., transformation matrix of ILR)
d1	alr reference element Sigma is already expressed with respect to
d2	alr reference element Sigma is to be expressed with respect to

**Value**

matrix

---

```
create_default_ilr_base
```

*Create a default ILR base*

---

**Description**

Create a default ILR base

**Usage**

```
create_default_ilr_base(D)
```

**Arguments**

D	the number of parts (e.g., number of columns in untransformed data)
---	---

**Value**

A matrix

---

fido\_package

*fido: Fitting and Analysis of Multinomial Logistic Normal Models*

---

**Description**

Provides methods for fitting and inspection of Bayesian Multinomial Logistic Normal Models using MAP estimation and Laplace Approximation. Key functionality is implemented in C++ for scalability.

**Author(s)**

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**See Also**

Useful links:

- <https://jsilve24.github.io/fido/>
- Report bugs at <https://github.com/jsilve24/fido/issues>

---

fido\_transforms

*Transform Fit fido Parameters to other representations*

---

**Description**

These are a collection of convenience functions for transforming fido fit objects to a number of different representations including ILR bases, CLR coordinates, ALR coordinates, and proportions.

**Usage**

```

to_proportions(m)

to_alr(m, d)

to_ilr(m, V = NULL)

to_clr(m)

## S3 method for class 'pibblefit'
to_proportions(m)

## S3 method for class 'orthusfit'
to_proportions(m)

## S3 method for class 'pibblefit'
to_alr(m, d)

## S3 method for class 'orthusfit'
to_alr(m, d)

## S3 method for class 'pibblefit'
to_ilr(m, V = NULL)

## S3 method for class 'orthusfit'
to_ilr(m, V = NULL)

## S3 method for class 'pibblefit'
to_clr(m)

## S3 method for class 'orthusfit'
to_clr(m)

```

**Arguments**

m	object of class pibblefit or orthusfit (e.g., output of <a href="#">pibble</a> or <a href="#">orthus</a> )
d	(integer) multinomial category to take as new alr reference
V	(matrix) contrast matrix for ILR basis to transform into to (defaults to <code>create_default_ilr_base(D)</code> )

**Details**

For orthus, transforms only applied to log-ratio parameters

Note: that there is a degeneracy of representations for a covariance matrix represented in terms of proportions. As such the function `to_proportions` does not attempt to transform parameters `Sigma` or prior `Xi` and instead just removes them from the pibblefit object returned.

**Value**

object

---

gather\_array

*Gather Multidimensional Array to Tidy Tibble*

---

**Description**

Gather Multidimensional Array to Tidy Tibble

**Usage**

```
gather_array(a, value, ..., .id = NULL)
```

**Arguments**

a	multidimensional array
value	unquoted name of column with values (defaults to "var")
...	unquoted dimension names (defaults to "dim_1", "dim_2", etc...)
.id	if specified, name for column created with name of a captured

**Value**

data.frame

**See Also**

spread\_array

**Examples**

```
a <- array(1:100, dim = c(10, 5, 2))
gather_array(a, sequence, A, B, C)
```

---

kernels *Multivariate RBF Kernel*


---

**Description**

Designed to be partially specified. (see examples)

**Usage**

```
SE(X, sigma = 1, rho = median(as.matrix(dist(t(X)))), jitter = 1e-10)
```

```
LINEAR(X, sigma = 1, c = rep(0, nrow(X)))
```

**Arguments**

X	covariate (dimension Q x N; i.e., covariates x samples)
sigma	scalar parameter
rho	scalar bandwidth parameter
jitter	small scalar to add to off-diagonal of gram matrix (for numerical underflow issues)
c	vector parameter defining intercept for linear kernel

**Details**

Gram matrix G is given by

SE (squared exponential):

$$G = \sigma^2 * \exp(-[(X - c)'(X - c)]/(s * \rho^2))$$

LINEAR:

$$G = \sigma^2 * (X - c)'(X - c)$$

**Value**

Gram Matrix (N x N) (e.g., the Kernel evaluated at each pair of points)

lambda\_to\_iqlr

*Transform Lambda into IQLR (Inter-Quantile Log-Ratio)***Description**

Takes idea from Wu et al. (citation below) and calculates IQLR for Lambda, potentially useful if you believe there is an invariant group of categories (e.g., taxa / genes) that are not changing (in absolute abundance) between samples. IQLR is defined as

$$IQLR_x = \log(x_i/g(IQVF))$$

for  $i$  in  $1, \dots, D$ . IQVF are the CLR coordinates whose variance is within the inter-quantile range (defined by probs argument to this function). A different IQVF is fit for each posterior sample as the IQVFs are calculated based on posterior estimates for Lambda. The variance of a CLR coordinate is defined as the norm of each row of `Lambda[,focus.cov]` (i.e., the covariation in Eta, explained by those covariates). This definition of variance allows uses to exclude variation from technical / trivial sources in calculation of IQVF/IQLR.

**Usage**

```
lambda_to_iqlr(m, focus.cov = NULL, probs = c(0.25, 0.75))
```

**Arguments**

<code>m</code>	object of class <code>pibblefit</code> (e.g., output of <code>pibble</code> )
<code>focus.cov</code>	vector of integers or characters specifying columns (covariates) of Lambda to include in calculating IQLR (if NULL, default, then uses all covariates)
<code>probs</code>	bounds for categories (i.e., features / genes / taxa) to include in calculation of iqlr (smaller bounds means more stringent inclusion criteria)

**Details**

Primarily intended for doing differential expression analysis under assumption that only small group of categories (e.g., taxa / genes) are changing

**Value**

array of dimension (D, Q, iter) where D is number of taxa, Q is number of covariates, and iter is number of posterior samples.

**References**

Jia R. Wu, Jean M. Macklaim, Briana L. Genge, Gregory B. Gloor (2017) Finding the center: corrections for asymmetry in high-throughput sequencing datasets. arxiv:1704.01841v1

**Examples**

```
sim <- pibble_sim()
fit <- pibble(sim$Y, sim$X)
# Use first two covariates to define iqlr, just show first 5 samples
lambda_to_iqlr(fit, 1:2)[,1:5]
```

---

**lmgamma***Log of Multivariate Gamma Function - Gamma\_p(a)*

---

**Description**

Log of Multivariate Gamma Function - Gamma\_p(a)

**Usage**

```
lmgamma(a, p)
```

**Arguments**

a                    defined by Gamma\_p(a)  
p                    defined by Gamma\_p(a)

**Value**

Numeric

**References**

[https://en.wikipedia.org/wiki/Multivariate\\_gamma\\_function](https://en.wikipedia.org/wiki/Multivariate_gamma_function)

---

**lmgamma\_deriv***Derivative of Log of Multivariate Gamma Function - Gamma\_p(a)*

---

**Description**

Derivative of Log of Multivariate Gamma Function - Gamma\_p(a)

**Usage**

```
lmgamma_deriv(a, p)
```

**Arguments**

a	defined by Gamma_p(a)
p	defined by Gamma_p(a)

**Value**

Numeric

**References**

[https://en.wikipedia.org/wiki/Multivariate\\_gamma\\_function](https://en.wikipedia.org/wiki/Multivariate_gamma_function)

---

loglikPibbleCollapsed *Calculations for the Collapsed Pibble Model*

---

**Description**

Functions providing access to the Log Likelihood, Gradient, and Hessian of the collapsed pibble model. Note: These are convenience functions but are not as optimized as direct coding of the PibbleCollapsed C++ class due to a lack of Memoization. By contrast function optimPibbleCollapsed is much more optimized and massively cuts down on repeated calculations. A more efficient Rcpp module based implementation of these functions may following if the future. For model details see [optimPibbleCollapsed](#) documentation

**Usage**

```
loglikPibbleCollapsed(Y, epsilon, ThetaX, KInv, AInv, eta, sylv = FALSE)
```

```
gradPibbleCollapsed(Y, epsilon, ThetaX, KInv, AInv, eta, sylv = FALSE)
```

```
hessPibbleCollapsed(Y, epsilon, ThetaX, KInv, AInv, eta, sylv = FALSE)
```

**Arguments**

Y	D x N matrix of counts
epsilon	(must be > D)
ThetaX	D-1 x N matrix formed by Theta*X (Theta is Prior mean for regression coefficients)
KInv	Inverse of K for LTP (for Pibble defined as KInv = solve(Xi))
AInv	Inverse of A for LTP (for Pibble defined as AInv = solve(diag(N)+ X'GammaX))
eta	matrix (D-1)xN of parameter values at which to calculate quantities
sylv	(default:false) if true and if N < D-1 will use sylvester determinant identity to speed computation

**Value**

see below

- loglikPibbleCollapsed - double
- gradPibbleCollapsed - vector
- hessPibbleCollapsed- matrix

**Examples**

```

D <- 10
Q <- 2
N <- 30

# Simulate Data
Sigma <- diag(sample(1:8, D-1, replace=TRUE))
Sigma[2, 3] <- Sigma[3,2] <- -1
Gamma <- diag(sqrt(rnorm(Q)^2))
Theta <- matrix(0, D-1, Q)
Phi <- Theta + t(chol(Sigma))%%matrix(rnorm(Q*(D-1)), nrow=D-1)%%chol(Gamma)
X <- matrix(rnorm(N*(Q-1)), Q-1, N)
X <- rbind(1, X)
Eta <- Phi%%X + t(chol(Sigma))%%matrix(rnorm(N*(D-1)), nrow=D-1)
Pi <- t(alrInv(t(Eta)))
Y <- matrix(0, D, N)
for (i in 1:N) Y[,i] <- rmultinom(1, sample(5000:10000), prob = Pi[,i])

# Priors
upsilon <- D+10
Xi <- Sigma*(upsilon-D)

# Precompute
KInv <- solve(Xi)
AInv <- solve(diag(N)+ t(X)%%Gamma%%X)
ThetaX <- Theta%%X

loglikPibbleCollapsed(Y, upsilon, ThetaX, KInv, AInv, Eta)
gradPibbleCollapsed(Y, upsilon, ThetaX, KInv, AInv, Eta)[1:5]
hessPibbleCollapsed(Y, upsilon, ThetaX, KInv, AInv, Eta)[1:5,1:5]

```

---

mallard

*Data from Silverman et al. (2018) Microbiome*


---

**Description**

High Resolution (hourly and daily) sampling of 4 in vitro artificial gut models with many technical replicates to identify technical variation.

**Usage**

```
data(mallard)
```

**Format**

A list containing "otu\_table", "sample\_data", "tax\_table", and "refseq".

**Details**

This data is at the sequence variant level. Data at the family level processed as in Silverman et al. 2018 is given in [mallard\\_family](#)

**References**

Silverman et al. "Dynamic linear models guide design and analysis of microbiota studies within artificial human guts". *Microbiome* 2018 6:202

---

mallard\_family

*Data from Silverman et al. (2018) Microbiome*

---

**Description**

High Resolution (hourly and daily) sampling of 4 in vitro artificial gut models with many technical replicates to identify technical variation.

**Usage**

```
data(mallard_family)
```

**Format**

A list containing "otu\_table", "sample\_data", "tax\_table", and "refseq".

**Details**

This data is at the family level and processed as in Silverman et al. 2018. Data at the sequence variant level without preprocessing is given in [mallard](#)

**References**

Silverman et al. "Dynamic linear models guide design and analysis of microbiota studies within artificial human guts". *Microbiome* 2018 6:202

---

metadata

*Data from Silverman et al. (2019) bioRxiv*

---

### Description

Mock communities and calibration samples created for measuring and validating model of PCR bias. This data has been preprocessed as in the original manuscript.

### Format

a data.frame metadata associated with the counts matrix ‘Y’

### References

Justin D. Silverman, Rachael J. Bloom, Sharon Jiang, Heather K. Durand, Sayan Mukherjee, Lawrence A. David. (2019) Measuring and Mitigating PCR Bias in Microbiome Data. bioRxiv 604025; doi: <https://doi.org/10.1101/604025>

---

miniclo

*Closure operator*

---

### Description

Closure operator

### Usage

```
miniclo(x)
```

### Arguments

x                      vector or matrix (rows are samples, parts are columns) of data in simplex

### Value

x with row entries divided by sum of row (converts vectors to row matrices)

### Examples

```
x <- matrix(runif(30), 10, 3)
x <- miniclo(x)
```

---

miniclo_array	<i>Closure Operation applied to array on margin</i>
---------------	---

---

**Description**

Array version of `miniclo`.

**Usage**

```
miniclo_array(x, parts)
```

**Arguments**

x	multidimensional array
parts	index of dimension of x that represents parts (e.g., compositional variables)

**Value**

array

**Examples**

```
x <- array(1:100, dim=c(10, 5, 2))
miniclo_array(x, parts=2)
```

---

mongrel-deprecated	<i>mongrel</i>
--------------------	----------------

---

**Description**

This function is deprecated, please use `pibble` instead.

**Usage**

```
mongrel(
  Y = NULL,
  X = NULL,
  epsilon = NULL,
  Theta = NULL,
  Gamma = NULL,
  Xi = NULL,
  init = NULL,
  pars = c("Eta", "Lambda", "Sigma"),
  ...
)
```

**Arguments**

Y	D x N matrix of counts (if NULL uses priors only)
X	Q x N matrix of covariates (design matrix) (if NULL uses priors only, must be present to sample Eta)
upsilon	dof for inverse wishart prior (numeric must be > D) (default: D+3)
Theta	(D-1) x Q matrix of prior mean for regression parameters (default: matrix(0, D-1, Q))
Gamma	QxQ prior covariance matrix (default: diag(Q))
Xi	(D-1)x(D-1) prior covariance matrix (default: ALR transform of diag(1)*(upsilon-D)/2 - this is essentially iid on "base scale" using Aitchison terminology)
init	(D-1) x N initialization for Eta for optimization
pars	character vector of posterior parameters to return
...	arguments passed to <a href="#">optimPibbleCollapsed</a> and <a href="#">uncollapsePibble</a>

**Value**

An object of class pibblefit

---

name	<i>Generic method for applying names to an object</i>
------	---

---

**Description**

Intended to be called internally by package

**Usage**

```
name(m, ...)
```

**Arguments**

m	object
...	other arguments to be passed

**Value**

object of same class but with names applied to dimensions

---

name.orthusfit	<i>S3 for orthusfit apply names to orthusfit object</i>
----------------	---

---

**Description**

To avoid confusion, assigned default names to multinomial categories (c1 etc...) and zdimensions (z1 etc...)

**Usage**

```
## S3 method for class 'orthusfit'
name(m, ...)
```

**Arguments**

m	object of class orthusfit
...	currently ignored

**Value**

object of class orthusfit

---

name.pibblefit	<i>S3 for pibblefit apply names to pibblefit object</i>
----------------	---

---

**Description**

S3 for pibblefit apply names to pibblefit object

**Usage**

```
## S3 method for class 'pibblefit'
name(m, ...)
```

**Arguments**

m	object of class pibblefit
...	currently ignored

**Value**

object of class pibblefit

---

`names_covariates.pibblefit`*Generic method for getting and setting dimension names of fit object*

---

**Description**

Generic method for getting and setting dimension names of fit object

**Usage**

```
## S3 method for class 'pibblefit'  
names_covariates(m)  
  
## S3 method for class 'pibblefit'  
names_samples(m)  
  
## S3 method for class 'pibblefit'  
names_categories(m)  
  
## S3 method for class 'pibblefit'  
names_coords(m)  
  
## S3 replacement method for class 'pibblefit'  
names_covariates(m) <- value  
  
## S3 replacement method for class 'pibblefit'  
names_samples(m) <- value  
  
## S3 replacement method for class 'pibblefit'  
names_categories(m) <- value  
  
names_covariates(m)  
  
names_samples(m)  
  
names_categories(m)  
  
names_coords(m)  
  
names_covariates(m) <- value  
  
names_samples(m) <- value  
  
names_categories(m) <- value
```

**Arguments**

m	object
value	character vector (or NULL)

**Details**

names\_coords is different than names\_categories. names\_categories provides access to the basic names of each multinomial category. In contrast, names\_coords provides access to the names of the coordinates in which an object is represented. These coordinate names are based on the category names. For example, category names may be, (OTU1, ..., OTUD) where as coordinate names could be (log(OTU1/OTUD), etc...) if object is in default coordinate system.

**Value**

A vector of names

---

ncategories.pibblefit *Generic method for accessing model fit dimensions*

---

**Description**

Generic method for accessing model fit dimensions

**Usage**

```
## S3 method for class 'pibblefit'
ncategories(m)
```

```
## S3 method for class 'pibblefit'
nsamples(m)
```

```
## S3 method for class 'pibblefit'
ncovariates(m)
```

```
## S3 method for class 'pibblefit'
niter(m)
```

```
## S3 method for class 'orthusfit'
ncategories(m)
```

```
## S3 method for class 'orthusfit'
nsamples(m)
```

```
## S3 method for class 'orthusfit'
ncovariates(m)
```

```

## S3 method for class 'orthusfit'
niter(m)

ncategories(m)

nsamples(m)

ncovariates(m)

niter(m)

```

### Arguments

`m` An object of class `pibblefit`

### Details

An alternative approach to accessing these dimensions is to access them directly from the `pibblefit` object using list indexing. `*ncategories` is equivalent to `m$D` `*nsamples` is equivalent to `m$N` `*ncovariates` is equivalent to `m$Q`

### Value

integer

---

`optimPibbleCollapsed` *Function to Optimize the Collapsed Pibble Model*

---

### Description

See details for model. Should likely be followed by function [uncollapsePibble](#). Notation: `N` is number of samples, `D` is number of multinomial categories, and `Q` is number of covariates.

### Usage

```

optimPibbleCollapsed(
  Y,
  epsilon,
  ThetaX,
  KInv,
  AInv,
  init,
  n_samples = 2000L,
  calcGradHess = TRUE,
  b1 = 0.9,
  b2 = 0.99,
  step_size = 0.003,
  epsilon = 1e-06,

```

```

eps_f = 1e-10,
eps_g = 1e-04,
max_iter = 10000L,
verbose = FALSE,
verbose_rate = 10L,
decomp_method = "cholesky",
optim_method = "lbfgs",
eigvalthresh = 0,
jitter = 0,
multDirichletBoot = -1,
useSylv = TRUE,
ncores = -1L,
seed = -1L
)

```

### Arguments

Y	D x N matrix of counts
epsilon	(must be > D)
ThetaX	D-1 x N matrix formed by $\Theta * X$ ( $\Theta$ is Prior mean for regression coefficients)
KInv	D-1 x D-1 precision matrix (inverse of $X_i$ )
AInv	N x N precision matrix given by $(I_N + X' * \Gamma * X)^{-1}$
init	D-1 x N matrix of initial guess for eta used for optimization
n_samples	number of samples for Laplace Approximation (=0 very fast as no inversion or decomposition of Hessian is required)
calcGradHess	if n_samples=0 should Gradient and Hessian still be calculated using closed form solutions?
b1	(ADAM) 1st moment decay parameter (recommend 0.9) "aka momentum"
b2	(ADAM) 2nd moment decay parameter (recommend 0.99 or 0.999)
step_size	(ADAM) step size for descent (recommend 0.001-0.003)
epsilon	(ADAM) parameter to avoid divide by zero
eps_f	(ADAM) normalized function improvement stopping criteria
eps_g	(ADAM) normalized gradient magnitude stopping criteria
max_iter	(ADAM) maximum number of iterations before stopping
verbose	(ADAM) if true will print stats for stopping criteria and iteration number
verbose_rate	(ADAM) rate to print verbose stats to screen
decomp_method	decomposition of hessian for Laplace approximation 'eigen' (more stable-slightly, slower) or 'cholesky' (less stable, faster, default)
optim_method	(default:"lbfgs") or "adam"
eigvalthresh	threshold for negative eigenvalues in decomposition of negative inverse hessian (should be <=0)

jitter	(default: 0) if >=0 then adds that factor to diagonal of Hessian before decomposition (to improve matrix conditioning)
multDirichletBoot	if >0 then it overrides laplace approximation and samples eta efficiently at MAP estimate from pseudo Multinomial-Dirichlet posterior.
useSylv	(default: true) if N<D-1 uses Sylvester Determinant Identity to speed up calculation of log-likelihood and gradients.
ncores	(default:-1) number of cores to use, if ncores==-1 then uses default from OpenMP typically to use all available cores.
seed	(random seed for Laplace approximation – integer)

### Details

Notation: Let  $Z_j$  denote the J-th row of a matrix Z. Model:

$$Y_j \sim \text{Multinomial}(\pi_j)$$

$$\pi_j = \Phi^{-1}(\eta_j)$$

$$\eta \sim T_{D-1,N}(v, \Theta X, K, A)$$

Where  $A = I_N + X\Gamma X'$ , K is a (D-1)x(D-1) covariance matrix,  $\Gamma$  is a Q x Q covariance matrix, and  $\Phi^{-1}$  is ALRInv\_D transform.

Gradient and Hessian calculations are fast as they are computed using closed form solutions. That said, the Hessian matrix can be quite large [ $N*(D-1) \times N*(D-1)$ ] and storage may be an issue.

Note: Warnings about large negative eigenvalues can either signal that the optimizer did not reach an optima or (more commonly in my experience) that the prior / degrees of freedom for the covariance (given by parameters `epsilon` and `KInv`) were too specific and at odds with the observed data. If you get this warning try the following.

1. Try restarting the optimization using a different initial guess for eta
2. Try decreasing (or even increasing) `step_size` (by increments of 0.001 or 0.002) and increasing `max_iter` parameters in optimizer. Also can try increasing `b1` to 0.99 and decreasing `eps_f` by a few orders of magnitude
3. Try relaxing prior assumptions regarding covariance matrix. (e.g., may want to consider decreasing parameter `epsilon` closer to a minimum value of D)
4. Try adding small amount of jitter (e.g., set `jitter=1e-5`) to address potential floating point errors.

### Value

List containing (all with respect to found optima)

1. LogLik - Log Likelihood of collapsed model (up to proportionality constant)
2. Gradient - (if `calcGradHess=true`)
3. Hessian - (if `calcGradHess=true`) of the POSITIVE LOG POSTERIOR
4. Pars - Parameter value of eta at optima

5. Samples - (D-1) x N x n\_samples array containing posterior samples of eta based on Laplace approximation (if n\_samples>0)
6. Timer - Vector of Execution Times
7. logInvNegHessDet - the log determinant of the covariacne of the Laplace approximation, useful for calculating marginal likelihood
8. logMarginalLikelihood - A calculation of the log marginal likelihood based on the laplace approximation

## References

- S. Ruder (2016) *An overview of gradient descent optimization algorithms*. arXiv 1609.04747
- JD Silverman K Roche, ZC Holmes, LA David, S Mukherjee. *Bayesian Multinomial Logistic Normal Models through Marginally Latent Matrix-T Processes*. 2022, Journal of Machine Learning

## See Also

[uncollapsePibble](#)

## Examples

```
sim <- pibble_sim()

# Fit model for eta
fit <- optimPibbleCollapsed(sim$Y, sim$upsilon, sim$Theta*%sim$X, sim$KInv,
                           sim$AInv, random_pibble_init(sim$Y))
```

---

orthusfit

*Create orthusfit object*

---

## Description

Create orthusfit object

## Usage

```
orthusfit(
  D,
  N,
  Q,
  P,
  coord_system,
  iter = NULL,
  alr_base = NULL,
  ilr_base = NULL,
  Eta = NULL,
  Lambda = NULL,
  Sigma = NULL,
```

```

Sigma_default = NULL,
Z = NULL,
Y = NULL,
X = NULL,
epsilon = NULL,
Theta = NULL,
Xi = NULL,
Xi_default = NULL,
Gamma = NULL,
init = NULL,
names_categories = NULL,
names_samples = NULL,
names_Zdimensions = NULL,
names_covariates = NULL
)

```

### Arguments

D	number of multinomial categories
N	number of samples
Q	number of covariates
P	Dimension of second dataset (e.g., <code>nrows(Z)</code> )
coord_system	coordinate system objects are represented in (options include "alr", "clr", "ilr", and "proportions")
iter	number of posterior samples
alr_base	integer category used as reference (required if <code>coord_system=="alr"</code> )
ilr_base	(D x D-1) contrast matrix (required if <code>coord_system=="ilr"</code> )
Eta	Array of samples of Eta
Lambda	Array of samples of Lambda
Sigma	Array of samples of Sigma (null if <code>coord_system=="proportions"</code> )
Sigma_default	Array of samples of Sigma in alr base D, used if <code>coord_system=="proportions"</code>
Z	PxN matrix of real valued observations
Y	DxN matrix of observed counts
X	QxN design matrix
epsilon	scalar prior dof of inverse wishart prior
Theta	prior mean of Lambda
Xi	Matrix of prior covariance for inverse wishart (null if <code>coord_system=="proportions"</code> )
Xi_default	Matrix of prior covariance for inverse wishart in alr base D (used if <code>coord_system=="proportions"</code> )
Gamma	QxQ covariance matrix prior for Lambda
init	matrix initial guess for Lambda used for optimization
names_categories	character vector

```

names_samples  character vector
names_Zdimensions
                character vector
names_covariates
                character vector

```

**Value**

object of class orthusfit

**See Also**

[pibble](#)

---

orthus_fit	<i>Interface to fit orthus models</i>
------------	---------------------------------------

---

**Description**

This function is largely a more user friendly wrapper around [optimPibbleCollapsed](#) and [uncollapsePibble](#) for fitting orthus models. See details for model specification. Notation: N is number of samples, P is the number of dimensions of observations in the second dataset, D is number of multinomial categories, Q is number of covariates, iter is the number of samples of eta (e.g., the parameter n\_samples in the function [optimPibbleCollapsed](#))

**Usage**

```

orthus(
  Y = NULL,
  Z = NULL,
  X = NULL,
  epsilon = NULL,
  Theta = NULL,
  Gamma = NULL,
  Xi = NULL,
  init = NULL,
  pars = c("Eta", "Lambda", "Sigma"),
  ...
)

```

**Arguments**

Y	D x N matrix of counts (if NULL uses priors only)
Z	P x N matrix of counts (if NULL uses priors only - must be present/absent if Y is present/absent)
X	Q x N matrix of covariates (design matrix) (if NULL uses priors only, must be present to sample Eta)

epsilon	dof for inverse wishart prior (numeric must be > D) (default: D+3)
Theta	(D-1+P) x Q matrix of prior mean for regression parameters (default: matrix(0, D-1+P, Q))
Gamma	QxQ prior covariance matrix (default: diag(Q))
Xi	(D-1+P)x(D-1+P) prior covariance matrix (default: ALR transform of diag(1)*(epsilon-D)/2 - this is essentially iid on "base scale" using Aitchison terminology)
init	(D-1) x Q initialization for Eta for optimization
pars	character vector of posterior parameters to return
...	arguments passed to <a href="#">optimPibbleCollapsed</a> and <a href="#">uncollapsePibble</a>

### Details

the full model is given by:

$$\begin{aligned}
 Y_j &\sim \text{Multinomial}(\pi_j) \\
 \pi_j &= \Phi^{-1}(\eta_j) \\
 \text{cbind}(\eta, Z) &\sim \text{MN}_{D-1+P \times N}(\Lambda X, \Sigma, I_N) \\
 \Lambda &\sim \text{MN}_{D-1+P \times Q}(\Theta, \Sigma, \Gamma) \\
 \Sigma &\sim \text{InvWish}(v, \Xi)
 \end{aligned}$$

Where  $\Gamma$  is a  $Q \times Q$  covariance matrix, and  $\Phi^{-1}$  is ALRInv\_D transform. That is, the orthus model models the latent multinomial log-ratios (Eta) and the observations of the second dataset jointly as a linear model. This allows Sigma to also describe the covariation between the two datasets.

Default behavior is to use MAP estimate for uncollapsing the LTP model if laplace approximation is not preformed.

### Value

an object of class pibblefit

### References

JD Silverman K Roche, ZC Holmes, LA David, S Mukherjee. Bayesian Multinomial Logistic Normal Models through Marginally Latent Matrix-T Processes. 2019, arXiv e-prints, arXiv:1903.11695

### See Also

[fido\\_transforms](#) provide convenience methods for transforming the representation of pibblefit objects (e.g., conversion to proportions, alr, clr, or ilr coordinates.)

[access\\_dims](#) provides convenience methods for accessing dimensions of pibblefit object

### Examples

```
sim <- orthus_sim()
fit <- orthus(sim$Y, sim$Z, sim$X)
```

---

orthus\_lr\_transforms *Log-Ratio transforms for orthus objects*

---

### Description

Log-Ratio transforms for orthus objects

### Usage

oglr(x, s, V)

oglrInv(x, s, V)

oalr(x, s, d = NULL)

oalrInv(y, s, d = NULL)

oilr(x, s, V = NULL)

oilrInv(y, s, V = NULL)

oclr(x, s)

oclrInv(x, s)

### Arguments

x	orthus data array (e.g., first s rows are multinomial parameters or log-ratios)
s	first s rows of x are transformed
V	transformation matrix (defines transform)
d	for ALR, which component (integer position) to take as reference (default is ncol(x)) for alrInv corresponds to column position in untransformed matrix.
y	orthus data array (e.g., first s rows are multinomial parameters or log-ratios)

### Value

A matrix

---

orthus_sim	<i>Simulate simple orthus dataset and priors (for testing)</i>
------------	--

---

**Description**

Simulate simple orthus dataset and priors (for testing)

**Usage**

```
orthus_sim(
  D = 10,
  P = 10,
  N = 30,
  Q = 2,
  use_names = TRUE,
  true_priors = FALSE
)
```

**Arguments**

D	number of multinomial categories
P	number of dimensions of second dataset Z
N	number of samples
Q	number of covariates (first one is an intercept, must be > 1)
use_names	should samples, covariates, and categories be named
true_priors	should Xi and upsilon be chosen to have mean at true simulated value

**Value**

list

**Examples**

```
sim <- orthus_sim()
```

---

orthus_tidy_samples	<i>Convert orthus samples of Eta Lambda and Sigma to tidy format</i>
---------------------	--

---

**Description**

Combines them all into a single tibble, see example for formatting and column headers. Primarily designed to be used by [summary.orthusfit](#).

**Usage**

```
orthus_tidy_samples(m, use_names = FALSE, as_factor = FALSE)
```

**Arguments**

m	an object of class orthusfit
use_names	should dimension indices be replaced by dimension names if provided in data used to fit pibble model.
as_factor	if use_names should names be returned as factor?

**Value**

tibble

**Examples**

```
sim <- orthus_sim()
fit <- orthus(sim$Y, sim$Z, sim$X)
fit_tidy <- orthus_tidy_samples(fit, use_names=TRUE)
head(fit_tidy)
```

---

pcrbias\_mock

*Data from Silverman et al. (2019) bioRxiv*

---

**Description**

Mock communities and calibration samples created for measuring and validating model of PCR bias. This data has been preprocessed as in the original manuscript.

**Usage**

```
data(pcrbias_mock)
```

**Format**

an matrix Y (counts for each community member) and a data.frame metadata

**References**

Justin D. Silverman, Rachael J. Bloom, Sharon Jiang, Heather K. Durand, Sayan Mukherjee, Lawrence A. David. (2019) Measuring and Mitigating PCR Bias in Microbiome Data. bioRxiv 604025; doi: <https://doi.org/10.1101/604025>

---

pibblefit

*Create pibblefit object*

---

### Description

Create pibblefit object

### Usage

```
pibblefit(
  D,
  N,
  Q,
  coord_system,
  iter = NULL,
  alr_base = NULL,
  ilr_base = NULL,
  Eta = NULL,
  Lambda = NULL,
  Sigma = NULL,
  Sigma_default = NULL,
  Y = NULL,
  X = NULL,
  epsilon = NULL,
  Theta = NULL,
  Xi = NULL,
  Xi_default = NULL,
  Gamma = NULL,
  init = NULL,
  names_categories = NULL,
  names_samples = NULL,
  names_covariates = NULL
)
```

### Arguments

D	number of multinomial categories
N	number of samples
Q	number of covariates
coord_system	coordinate system objects are represented in (options include "alr", "clr", "ilr", and "proportions")
iter	number of posterior samples
alr_base	integer category used as reference (required if coord_system=="alr")
ilr_base	(D x D-1) contrast matrix (required if coord_system=="ilr")
Eta	Array of samples of Eta

Lambda	Array of samples of Lambda
Sigma	Array of samples of Sigma (null if coord_system=="proportions")
Sigma_default	Array of samples of Sigma in alr base D, used if coord_system=="proportions"
Y	DxN matrix of observed counts
X	QxN design matrix
upsilon	scalar prior dof of inverse wishart prior
Theta	prior mean of Lambda
Xi	Matrix of prior covariance for inverse wishart (null if coord_system=="proportions")
Xi_default	Matrix of prior covariance for inverse wishart in alr base D (used if coord_system=="proportions")
Gamma	QxQ covariance matrix prior for Lambda
init	matrix initial guess for Lambda used for optimization
names_categories	character vector
names_samples	character vector
names_covariates	character vector

**Value**

object of class pibblefit

**See Also**

[pibble](#)

---

pibble\_fit

*Interface to fit pibble models*

---

**Description**

This function is largely a more user friendly wrapper around [optimPibbleCollapsed](#) and [uncollapsePibble](#). See details for model specification. Notation: N is number of samples, D is number of multinomial categories, Q is number of covariates, iter is the number of samples of eta (e.g., the parameter n\_samples in the function [optimPibbleCollapsed](#))

**Usage**

```
pibble(
  Y = NULL,
  X = NULL,
  epsilon = NULL,
  Theta = NULL,
  Gamma = NULL,
  Xi = NULL,
```

```

    init = NULL,
    pars = c("Eta", "Lambda", "Sigma"),
    newdata = NULL,
    ...
)

## S3 method for class 'pibblefit'
refit(m, pars = c("Eta", "Lambda", "Sigma"), ...)

```

### Arguments

Y	D x N matrix of counts (if NULL uses priors only)
X	Q x N matrix of covariates (design matrix) (if NULL uses priors only, must be present to sample Eta)
upsilon	dof for inverse wishart prior (numeric must be > D) (default: D+3)
Theta	(D-1) x Q matrix of prior mean for regression parameters (default: matrix(0, D-1, Q))
Gamma	QxQ prior covariance matrix (default: diag(Q))
Xi	(D-1)x(D-1) prior covariance matrix (default: ALR transform of diag(1)*(upsilon-D)/2 - this is essentially iid on "base scale" using Aitchison terminology)
init	(D-1) x N initialization for Eta for optimization
pars	character vector of posterior parameters to return
newdata	Default is NULL. If non-null, newdata is used in the uncollapse sampler in place of X.
...	arguments passed to <a href="#">optimPibbleCollapsed</a> and <a href="#">uncollapsePibble</a>
m	object of class pibblefit

### Details

the full model is given by:

$$\begin{aligned}
 Y_j &\sim \text{Multinomial}(\pi_j) \\
 \pi_j &= \Phi^{-1}(\eta_j) \\
 \eta &\sim MN_{D-1 \times N}(\Lambda X, \Sigma, I_N) \\
 \Lambda &\sim MN_{D-1 \times Q}(\Theta, \Sigma, \Gamma) \\
 \Sigma &\sim \text{InvWish}(v, \Xi)
 \end{aligned}$$

Where  $\Gamma$  is a Q x Q covariance matrix, and  $\Phi^{-1}$  is ALRInv\_D transform.

Default behavior is to use MAP estimate for uncollapsing the LTP model if laplace approximation is not preformed.

### Value

an object of class pibblefit

**References**

JD Silverman K Roche, ZC Holmes, LA David, S Mukherjee. Bayesian Multinomial Logistic Normal Models through Marginally Latent Matrix-T Processes. 2019, arXiv e-prints, arXiv:1903.11695

**See Also**

[fido\\_transforms](#) provide convenience methods for transforming the representation of pibblefit objects (e.g., conversion to proportions, alr, clr, or ilr coordinates.)

[access\\_dims](#) provides convenience methods for accessing dimensions of pibblefit object

Generic functions including [summary](#), [print](#), [coef](#), [as.list](#), [predict](#), [name](#), and [sample\\_prior\\_name\\_dims](#)

Plotting functions provided by [plot](#) and [ppc](#) (posterior predictive checks)

**Examples**

```
sim <- pibble_sim()
fit <- pibble(sim$Y, sim$X)
```

---

pibble\_sim

*Simulate simple pibble dataset and priors (for testing)*

---

**Description**

Simulate simple pibble dataset and priors (for testing)

**Usage**

```
pibble_sim(D = 10, N = 30, Q = 2, use_names = TRUE, true_priors = FALSE)
```

**Arguments**

D	number of multinomial categories
N	number of samples
Q	number of covariates (first one is an intercept, must be > 1)
use_names	should samples, covariates, and categories be named
true_priors	should Xi and upsilon be chosen to have mean at true simulated value

**Value**

list

**Examples**

```
sim <- pibble_sim()
```

---

pibble\_tidy\_samples     *Convert pibble samples of Eta Lambda and Sigma to tidy format*

---

**Description**

Combines them all into a single tibble, see example for formatting and column headers. Primarily designed to be used by [summary.pibblefit](#).

**Usage**

```
pibble_tidy_samples(m, use_names = FALSE, as_factor = FALSE)
```

**Arguments**

m	an object of class pibblefit
use_names	should dimension indices be replaced by dimension names if provided in data used to fit pibble model.
as_factor	if use_names should names be returned as factor?

**Value**

tibble

**Examples**

```
sim <- pibble_sim()
fit <- pibble(sim$Y, sim$X)
fit_tidy <- pibble_tidy_samples(fit, use_names=TRUE)
head(fit_tidy)
```

---

plot.pibblefit     *Plot Summaries of Posterior Distribution of pibblefit Parameters*

---

**Description**

Plot Summaries of Posterior Distribution of pibblefit Parameters

**Usage**

```
## S3 method for class 'pibblefit'
plot(x, ...)
```

**Arguments**

x	an object of class pibblefit
...	other arguments passed to plot.pibblefit (see details)

## Details

Other arguments:

- ‘par’ parameter to plot (options: Lambda, Eta, and Sigma) (default="Lambda")
- ‘focus.cov’ vector of covariates to include in plot (plots all if NULL)
- ‘focus.coord’ vector of coordinates to include in plot (plots all if NULL)
- ‘focus.sample’ vector of samples to include in plot (plots all if NULL)
- ‘use\_names’ if TRUE, uses dimension names found in data as plot labels rather than using dimension integer indices.

## Value

ggplot object

## Examples

```
sim <- pibble_sim(N=10, D=4, Q=3)
fit <- pibble(sim$Y, sim$X)
plot(fit, par="Lambda")
plot(fit, par="Sigma")
```

---

ppc

*Generic method for visualizing posterior predictive checks*

---

## Description

Generic method for visualizing posterior predictive checks

## Usage

```
ppc(m, ...)
```

## Arguments

m	object
...	other arguments passed that control visualization

## Value

A plot

---

`ppc.pibblefit`*Visualization of Posterior Predictive Check of fit model*

---

## Description

Visualization of Posterior Predictive Check of fit model

## Usage

```
## S3 method for class 'pibblefit'  
ppc(m, ...)
```

## Arguments

<code>m</code>	an object of class <code>pibblefit</code>
<code>...</code>	other options passed to <code>ppc</code> (see details)

## Details

`ppc.pibblefit` accepts the following additional arguments:

- "type" type of plot (options "lines", "points", "bounds")
- "iter" number of samples from posterior predictive distribution to plot (currently must be  $\leq$  `m$iter`) if `type=="lines"` default is 50, if `type=="ribbon"` default is to use all available iterations.
- "from\_scratch" should predictions of Y come from fitted Eta or from predictions of Eta from posterior of Lambda? (default: false)

## Value

ggplot object

## Examples

```
sim <- pibble_sim()  
fit <- pibble(sim$Y, sim$X)  
ppc(fit)
```

---

ppc\_summary.pibblefit *Generic Method to Plot Posterior Predictive Summaries*

---

### Description

Generic Method to Plot Posterior Predictive Summaries

### Usage

```
## S3 method for class 'pibblefit'
ppc_summary(m, from_scratch = FALSE, ...)

ppc_summary(m, ...)
```

### Arguments

m	model object
from_scratch	should predictions of Y come from fitted Eta or from predictions of Eta from posterior of Lambda? (default: false)
...	other arguments to pass

### Value

vector

---

predict.basetfit *Predict using baset*

---

### Description

Predict using baset

### Usage

```
## S3 method for class 'basetfit'
predict(
  object,
  newdata = NULL,
  response = "Lambda",
  size = NULL,
  use_names = TRUE,
  summary = FALSE,
  iter = NULL,
  from_scratch = FALSE,
  ...
)
```

**Arguments**

object	An object of class pibblefit
newdata	An optional matrix for which to evaluate prediction.
response	Options = "Lambda":Mean of regression, "Eta", "Y": counts
size	the number of counts per sample if response="Y" (as vector or matrix), default if newdata=NULL and response="Y" is to use colsums of m\$Y. Otherwise uses median colsums of object\$Y as default. If passed as a matrix should have dimensions ncol(newdata) x iter.
use_names	if TRUE apply names to output
summary	if TRUE, posterior summary of predictions are returned rather than samples
iter	number of iterations to return if NULL uses object\$iter
from_scratch	should predictions of Y come from fitted Eta or from predictions of Eta from posterior of Lambda? (default: false)
...	other arguments passed to summarise_posterior

**Details**

currently only implemented for pibblefit objects in coord\_system "default" "alr", or "ilr".

**Value**

(if summary==FALSE) array D x N x iter; (if summary==TRUE) tibble with calculated posterior summaries

---

predict.pibblefit      *Predict response from new data*

---

**Description**

Predict response from new data

**Usage**

```
## S3 method for class 'pibblefit'
predict(
  object,
  newdata = NULL,
  response = "LambdaX",
  size = NULL,
  use_names = TRUE,
  summary = FALSE,
  iter = NULL,
  from_scratch = FALSE,
  ...
)
```

**Arguments**

object	An object of class pibblefit
newdata	An optional matrix for which to evaluate predictions. If NULL (default), the original data of the model is used.
response	Options = "LambdaX":Mean of regression, "Eta", "Y": counts
size	the number of counts per sample if response="Y" (as vector or matrix), default if newdata=NULL and response="Y" is to use colsums of m\$Y. Otherwise uses median colsums of m\$Y as default. If passed as a matrix should have dimensions ncol(newdata) x iter.
use_names	if TRUE apply names to output
summary	if TRUE, posterior summary of predictions are returned rather than samples
iter	number of iterations to return if NULL uses object\$iter
from_scratch	should predictions of Y come from fitted Eta or from predictions of Eta from posterior of Lambda? (default: false)
...	other arguments passed to summarise_posterior

**Details**

currently only implemented for pibblefit objects in coord\_system "default" "alr", or "ilr".

**Value**

(if summary==FALSE) array D x N x iter; (if summary==TRUE) tibble with calculated posterior summaries

**Examples**

```
sim <- pibble_sim()
fit <- pibble(sim$Y, sim$X)
predict(fit)[,1:2] # just show 2 samples
```

---

print.orthusfit      *Print dimensions and coordinate system information for orthusfit object.*

---

**Description**

Print dimensions and coordinate system information for orthusfit object.

**Usage**

```
## S3 method for class 'orthusfit'
print(x, summary = FALSE, ...)
```

**Arguments**

x                    an object of class orthusfit  
summary            if true also calculates and prints summary  
...                   other arguments to pass to summary function

**Value**

No direct return, prints out summary

**See Also**

[summary.orthusfit](#) summarizes posterior intervals

**Examples**

```
sim <- orthus_sim()
fit <- orthus(sim$Y, sim$Z, sim$X)
print(fit)
```

---

print.pibblefit	<i>Print dimensions and coordinate system information for pibblefit object.</i>
-----------------	---

---

**Description**

Print dimensions and coordinate system information for pibblefit object.

**Usage**

```
## S3 method for class 'pibblefit'
print(x, summary = FALSE, ...)
```

**Arguments**

x                    an object of class pibblefit  
summary            if true also calculates and prints summary  
...                   other arguments to pass to summary function

**Value**

No direct return, prints out summary

**See Also**

[summary.pibblefit](#) summarizes posterior intervals

**Examples**

```
sim <- pibble_sim()
fit <- pibble(sim$Y, sim$X)
print(fit)
```

r2

*Generic Method to Calculate R2 for Fitted Model***Description**

Generic Method to Calculate R2 for Fitted Model

**Usage**

```
r2(m, ...)
```

```
## S3 method for class 'pibblefit'
```

```
r2(m, covariates = NULL, ...)
```

```
## S3 method for class 'bassetfit'
```

```
r2(m, covariates = NULL, components = NULL, ...)
```

**Arguments**

m	model object
...	other arguments to pass
covariates	vector of indices for covariates to include in calculation of R2 (default:NULL means include all covariates by default). When non-null, all covariates not specified are set to zero for prediction.
components	vector of indices for components of the GP model to include in the calculation of R2, i.e. which elements in the list of Theta/Gamma should be used for calculating R2 (default:NULL means to include all components by default). When non-null, all components not specified are removed for prediction.

**Details**

Calculates Posterior over Linear Model R2 as:

$$1 - \frac{SS_{res}}{SS_{tot}}$$

where  $SS$  is defined in terms of trace of variances

Method of calculating R2 is multivariate version of the Bayesian R2 proposed by Gelman, Goodrich, Gabry, and Vehtari, 2019

Calculates Posterior over Basset Model R2 as:

$$1 - \frac{SS_{res}}{SS_{tot}}$$

Method of calculating R2 is multivariate version of the Bayesian R2 proposed by Gelman, Goodrich, Gabry, and Vehtari, 2019

### Value

vector

---

random_pibble_init	<i>Provide random initialization for pibble model</i>
--------------------	---

---

### Description

Randomly initializes based on ALR transform of counts plus random pseudocounts uniformly distributed between 0 and 1.

### Usage

```
random_pibble_init(Y)
```

### Arguments

Y                    matrix (D x N) of counts

### Details

Notation: N is number of samples and D is number of multinomial categories

### Value

(D-1) x N matrix

### Examples

```
Y <- matrix(sample(1:100, 100), 10, 10)
random_pibble_init(Y)
```

---

refit	<i>Generic method for fitting model from passed model fit object</i>
-------	--

---

**Description**

Generic method for fitting model from passed model fit object

**Usage**

```
refit(m, ...)
```

**Arguments**

m	object
...	other arguments passed that control fitting

**Value**

object of the same class as m

---

req	<i>Generic method for ensuring object contains required elements</i>
-----	--

---

**Description**

Intended to be called internally by package

**Usage**

```
req(m, r)
```

**Arguments**

m	object
r	vector of elements to test for

**Value**

throws error if required element is not present

---

req.orthusfit	<i>require elements to be non-null in orthusfit or throw error</i>
---------------	--

---

**Description**

require elements to be non-null in orthusfit or throw error

**Usage**

```
## S3 method for class 'orthusfit'  
req(m, r)
```

**Arguments**

m	object
r	vector of elements to test for

**Value**

None, throws an error if NULL

---

req.pibblefit	<i>require elements to be non-null in pibblefit or throw error</i>
---------------	--

---

**Description**

require elements to be non-null in pibblefit or throw error

**Usage**

```
## S3 method for class 'pibblefit'  
req(m, r)
```

**Arguments**

m	object
r	vector of elements to test for

**Value**

Nothing, throws an error if NULL

---

RISK\_CCFA

*Data from Gevers et al. (2014)*

---

**Description**

OTU data and metadata for 1,359 samples in a Crohn's disease study

**Usage**

```
data(RISK_CCFA)
```

**Format**

An otu table, sample data table, and taxonomy table.

**Details**

Study is described here: <https://pubmed.ncbi.nlm.nih.gov/24629344/>. Data was obtained from <https://github.com/twbattaglia/MicrobeDS>.

**References**

Gevers D, et al. The treatment-naive microbiome in new-onset Crohn's disease. *Cell Host Microbe*. 2014 Mar 12;15(3):382-392. doi: 10.1016/j.chom.2014.02.005. PMID: 24629344; PMCID: PMC4059512.

---

RISK\_CCFA\_otu

*Data from Gevers et al. (2014)*

---

**Description**

OTU data and metadata for 1,359 samples in a Crohn's disease study

**Usage**

```
data(RISK_CCFA)
```

**Format**

A matrix otu table.

**Details**

Study is described here: <https://pubmed.ncbi.nlm.nih.gov/24629344/>. Data was obtained from <https://github.com/twbattaglia/MicrobeDS>.

**References**

Gevers D, et al. The treatment-naive microbiome in new-onset Crohn's disease. *Cell Host Microbe*. 2014 Mar 12;15(3):382-392. doi: 10.1016/j.chom.2014.02.005. PMID: 24629344; PMCID: PMC4059512.

---

RISK_CCFA_sam	<i>Data from Gevers et al. (2014)</i>
---------------	---------------------------------------

---

**Description**

OTU data and metadata for 1,359 samples in a Crohn's disease study

**Usage**

```
data(RISK_CCFA)
```

**Format**

A sample data table.

**Details**

Study is described here: <https://pubmed.ncbi.nlm.nih.gov/24629344/>. Data was obtained from <https://github.com/twbattaglia/MicrobeDS>.

**References**

Gevers D, et al. The treatment-naive microbiome in new-onset Crohn's disease. *Cell Host Microbe*. 2014 Mar 12;15(3):382-392. doi: 10.1016/j.chom.2014.02.005. PMID: 24629344; PMCID: PMC4059512.

---

RISK_CCFA_tax	<i>Data from Gevers et al. (2014)</i>
---------------	---------------------------------------

---

**Description**

OTU data and metadata for 1,359 samples in a Crohn's disease study

**Usage**

```
data(RISK_CCFA)
```

**Format**

A taxonomy table.

## Details

Study is described here: <https://pubmed.ncbi.nlm.nih.gov/24629344/>. Data was obtained from <https://github.com/twbattaglia/MicrobeDS>.

## References

Gevers D, et al. The treatment-naive microbiome in new-onset Crohn's disease. *Cell Host Microbe*. 2014 Mar 12;15(3):382-392. doi: 10.1016/j.chom.2014.02.005. PMID: 24629344; PMCID: PMC4059512.

---

sample_prior	<i>Generic method for sampling from prior distribution of object</i>
--------------	--

---

## Description

Generic method for sampling from prior distribution of object

## Usage

```
sample_prior(m, n_samples = 2000L, ...)
```

## Arguments

m	object
n_samples	number of samples to produce
...	other arguments to be passed

## Value

object of the same class

---

sample_prior.pibblefit	<i>Sample from the prior distribution of pibblefit object</i>
------------------------	---

---

## Description

Note this can be used to sample from prior and then predict can be called to get counts or LambdaX ([predict.pibblefit](#))

**Usage**

```
## S3 method for class 'pibblefit'
sample_prior(
  m,
  n_samples = 2000L,
  pars = c("Eta", "Lambda", "Sigma"),
  use_names = TRUE,
  ...
)
```

**Arguments**

m	object of class pibblefit
n_samples	number of samples to produce
pars	parameters to sample
use_names	should names be used if available
...	currently ignored

**Details**

Could be greatly speed up in the future if needed by sampling directly from cholesky form of inverse wishart (currently implemented as header in this library - see MatDist.h).

**Value**

A pibblefit object

**Examples**

```
# Sample prior of already fitted pibblefit object
sim <- pibble_sim()
attach(sim)
fit <- pibble(Y, X)
head(sample_prior(fit))

# Sample prior as part of model fitting
m <- pibblefit(N=as.integer(sim$N), D=as.integer(sim$D), Q=as.integer(sim$Q),
              iter=2000L, epsilon=epsilon,
              Xi=Xi, Gamma=Gamma, Theta=Theta, X=X,
              coord_system="alr", alr_base=D)
m <- sample_prior(m)
plot(m) # plot prior distribution (defaults to parameter Lambda)
```

---

store_coord	<i>Holds information on coordinates system to later be reapplied</i>
-------------	--

---

**Description**

store\_coord stores coordinate information for pibblefit object and can be reapplied with function reapply\_coord. Some coordinate systems are not useful for computation and this makes it simple keep returned object from computations in the same coordinate system as the input. (Likely most useful inside of a package)

**Usage**

```
store_coord(m)
```

```
reapply_coord(m, l)
```

**Arguments**

m	object of class pibblefit
l	object returned by function store_coord

**Value**

store\_coord list with important information to identify c coordinate system of pibblefit object. reapply\_coord pibblefit object in coordinate system previously stored.

---

summarise_posterior	<i>Shortcut for summarize variable with quantiles and mean</i>
---------------------	--

---

**Description**

Shortcut for summarize variable with quantiles and mean

**Usage**

```
summarise_posterior(data, var, ...)
```

**Arguments**

data	tidy data frame
var	variable name (unquoted) to be summarised
...	other expressions to pass to summarise

**Details**

Notation: pX refers to the X% quantile

**Value**

data.frame

**Examples**

```
d <- data.frame("a"=sample(1:10, 50, TRUE),
               "b"=rnorm(50))

# Summarize posterior for b over grouping of a and also calculate
# minnum of b (in addition to normal statistics returned)
d <- dplyr::group_by(d, a)
summarise_posterior(d, b, mean.b = mean(b), min=min(b))
```

---

summary.orthusfit      *Summarise orthusfit object and print posterior quantiles*

---

**Description**

Default calculates median, mean, 50% and 95% credible interval

**Usage**

```
## S3 method for class 'orthusfit'
summary(
  object,
  pars = NULL,
  use_names = TRUE,
  as_factor = FALSE,
  gather_prob = FALSE,
  ...
)
```

**Arguments**

object	an object of class orthusfit
pars	character vector (default: c("Eta", "Lambda", "Sigma"))
use_names	should summary replace dimension indices with orthusfit names if names Y and X were named in call to <a href="#">orthus</a>
as_factor	if use_names and as_factor then returns names as factors (useful for maintaining orderings when plotting)
gather_prob	if TRUE then prints quantiles in long format rather than wide (useful for some plotting functions)
...	other expressions to pass to summarise (using name 'val' unquoted is probably what you want)

**Value**

A list

---

summary.pibblefit      *Summarise pibblefit object and print posterior quantiles*

---

### Description

Default calculates median, mean, 50% and 95% credible interval

### Usage

```
## S3 method for class 'pibblefit'
summary(
  object,
  pars = NULL,
  use_names = TRUE,
  as_factor = FALSE,
  gather_prob = FALSE,
  ...
)
```

### Arguments

object	an object of class pibblefit
pars	character vector (default: c("Eta", "Lambda", "Sigma"))
use_names	should summary replace dimension indices with pibblefit names if names Y and X were named in call to <a href="#">pibble</a>
as_factor	if use_names and as_factor then returns names as factors (useful for maintaining orderings when plotting)
gather_prob	if TRUE then prints quantiles in long format rather than wide (useful for some plotting functions)
...	other expressions to pass to summarise (using name 'val' unquoted is probably what you want)

### Value

A list

---

uncollapsePibble      *Uncollapse output from optimPibbleCollapsed to full pibble Model*

---

### Description

See details for model. Should likely be called following [optimPibbleCollapsed](#). Notation: N is number of samples, D is number of multinomial categories, Q is number of covariates, iter is the number of samples of eta (e.g., the parameter n\_samples in the function [optimPibbleCollapsed](#))

**Usage**

```
uncollapsePibble(
  eta,
  X,
  Theta,
  Gamma,
  Xi,
  epsilon,
  seed,
  ret_mean = FALSE,
  ncores = -1L
)
```

**Arguments**

eta	array of dimension (D-1) x N x iter (e.g., Pars output of function optimPibbleCollapsed)
X	matrix of covariates of dimension Q x N
Theta	matrix of prior mean of dimension (D-1) x Q
Gamma	covariance matrix of dimension Q x Q
Xi	covariance matrix of dimension (D-1) x (D-1)
epsilon	scalar (must be > D) degrees of freedom for InvWishart prior
seed	seed to use for random number generation
ret_mean	if true then uses posterior mean of Lambda and Sigma corresponding to each sample of eta rather than sampling from posterior of Lambda and Sigma (useful if Laplace approximation is not used (or fails) in optimPibbleCollapsed)
ncores	(default:-1) number of cores to use, if ncores==-1 then uses default from OpenMP typically to use all available cores.

**Details**

Notation: Let  $Z_j$  denote the J-th row of a matrix Z. While the collapsed model is given by:

$$Y_j \sim \text{Multinomial}(\pi_j)$$

$$\pi_j = \Phi^{-1}(\eta_j)$$

$$\eta \sim T_{D-1, N}(v, \Theta X, K, A)$$

Where  $A = I_N + X\Gamma X'$ ,  $K = \Xi$  is a (D-1)x(D-1) covariance matrix,  $\Gamma$  is a Q x Q covariance matrix, and  $\Phi^{-1}$  is ALRInv\_D transform.

The uncollapsed model (Full pibble model) is given by:

$$Y_j \sim \text{Multinomial}(\pi_j)$$

$$\pi_j = \Phi^{-1}(\eta_j)$$

$$\eta \sim MN_{D-1 \times N}(\Lambda X, \Sigma, I_N)$$

$$\Lambda \sim MN_{D-1 \times Q}(\Theta, \Sigma, \Gamma)$$

$$\Sigma \sim InvWish(v, \Xi)$$

This function provides a means of sampling from the posterior distribution of Lambda and Sigma given posterior samples of Eta from the collapsed model.

### Value

List with components

1. Lambda Array of dimension (D-1) x Q x iter (posterior samples)
2. Sigma Array of dimension (D-1) x (D-1) x iter (posterior samples)
3. The number of cores used
4. Timer

### References

JD Silverman K Roche, ZC Holmes, LA David, S Mukherjee. Bayesian Multinomial Logistic Normal Models through Marginally Latent Matrix-T Processes. 2019, arXiv e-prints, arXiv:1903.11695

### See Also

[optimPibbleCollapsed](#)

### Examples

```
sim <- pibble_sim()

# Fit model for eta
fit <- optimPibbleCollapsed(sim$Y, sim$upsilon, sim$Theta%*%sim$X, sim$KInv,
                           sim$AInv, random_pibble_init(sim$Y))

# Finally obtain samples from Lambda and Sigma
fit2 <- uncollapsePibble(fit$Samples, sim$X, sim$Theta,
                        sim$Gamma, sim$Xi, sim$upsilon,
                        seed=2849)
```

---

uncollapsePibble\_sigmaKnown

*Uncollapse output from optimPibbleCollapsed to full pibble Model  
when Sigma is known*

---

### Description

See details for model. Should likely be called following [optimPibbleCollapsed](#). Notation: N is number of samples, D is number of multinomial categories, Q is number of covariates, iter is the number of samples of eta (e.g., the parameter n\_samples in the function `optimPibbleCollapsed`)

**Usage**

```

uncollapsePibble_sigmaKnown(
  eta,
  X,
  Theta,
  Gamma,
  GammaComb,
  Xi,
  sigma,
  epsilon,
  seed,
  ret_mean = FALSE,
  linear = FALSE,
  ncores = -1L
)

```

**Arguments**

eta	array of dimension (D-1) x N x iter (e.g., Pars output of function optimPibbleCollapsed)
X	matrix of covariates of dimension Q x N
Theta	matrix of prior mean of dimension (D-1) x Q
Gamma	covariance matrix of dimension Q x Q
GammaComb	summed covariance matrix across additive components of dimension Q x Q.
Xi	covariance matrix of dimension (D-1) x (D-1)
sigma	known covariance matrix of dimension (D-1) x (D-1) x iter
epsilon	scalar (must be > D) degrees of freedom for InvWishart prior
seed	seed to use for random number generation
ret_mean	if true then uses posterior mean of Lambda and Sigma corresponding to each sample of eta rather than sampling from posterior of Lambda and Sigma (useful if Laplace approximation is not used (or fails) in optimPibbleCollapsed)
linear	Boolean. Is this for a linear parameter?
ncores	(default:-1) number of cores to use, if ncores==-1 then uses default from OpenMP typically to use all available cores.

**Details**

Notation: Let  $Z_j$  denote the J-th row of a matrix Z. While the collapsed model is given by:

$$Y_j \sim \text{Multinomial}(\pi_j)$$

$$\pi_j = \Phi^{-1}(\eta_j)$$

$$\eta \sim T_{D-1, N}(v, \Theta X, K, A)$$

Where  $A = I_N + X\Gamma X'$ ,  $K = \Xi$  is a (D-1)x(D-1) covariance matrix,  $\Gamma$  is a Q x Q covariance matrix, and  $\Phi^{-1}$  is ALRInv\_D transform.

The uncollapsed model (Full pibble model) is given by:

$$\begin{aligned} Y_j &\sim \text{Multinomial}(\pi_j) \\ \pi_j &= \Phi^{-1}(\eta_j) \\ \eta &\sim \text{MN}_{D-1 \times N}(\Lambda X, \Sigma, I_N) \\ \Lambda &\sim \text{MN}_{D-1 \times Q}(\Theta, \Sigma, \Gamma) \\ \Sigma &\sim \text{InvWish}(v, \Xi) \end{aligned}$$

This function provides a means of sampling from the posterior distribution of Lambda and Sigma given posterior samples of Eta from the collapsed model.

### Value

List with components

1. Lambda Array of dimension (D-1) x Q x iter (posterior samples)
2. Sigma Array of dimension (D-1) x (D-1) x iter (posterior samples)
3. The number of cores used
4. Timer

### References

JD Silverman K Roche, ZC Holmes, LA David, S Mukherjee. Bayesian Multinomial Logistic Normal Models through Marginally Latent Matrix-T Processes. 2019, arXiv e-prints, arXiv:1903.11695

### See Also

[optimPibbleCollapsed](#)

---

verify

*Generic method for verifying new objects*

---

### Description

Intended to be called internally by package or object creator

### Usage

```
verify(m, ...)
```

### Arguments

m	object
...	other arguments to be passed to verify

### Value

throws error if verify test fails

---

verify.bassetfit      *Simple verification of passed bassetfit object*

---

**Description**

Simple verification of passed bassetfit object

**Usage**

```
## S3 method for class 'bassetfit'  
verify(m, ...)
```

**Arguments**

m	an object of class bassetfit
...	not used

**Value**

throws error if any verification tests fail

---

verify.orthusfit      *Simple verification of passed orthusfit object*

---

**Description**

Simple verification of passed orthusfit object

**Usage**

```
## S3 method for class 'orthusfit'  
verify(m, ...)
```

**Arguments**

m	an object of class orthusfit
...	not used

**Value**

throws error if any verification tests fail

---

`verify.pibblefit`      *Simple verification of passed pibblefit object*

---

**Description**

Simple verification of passed pibblefit object

**Usage**

```
## S3 method for class 'pibblefit'  
verify(m, ...)
```

**Arguments**

`m`                    an object of class pibblefit  
`...`                not used

**Value**

throws error if any verification tests fail

---

Y                              *Data from Silverman et al. (2019) bioRxiv*

---

**Description**

Mock communities and calibration samples created for measuring and validating model of PCR bias. This data has been preprocessed as in the original manuscript.

**Format**

an matrix Y (counts for each community member)

**References**

Justin D. Silverman, Rachael J. Bloom, Sharon Jiang, Heather K. Durand, Sayan Mukherjee, Lawrence A. David. (2019) Measuring and Mitigating PCR Bias in Microbiome Data. bioRxiv 604025; doi: <https://doi.org/10.1101/604025>

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