

# Package ‘NewWave’

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**Type** Package

**Title** Negative binomial model for scRNA-seq

**Version** 1.21.0

**Description** A model designed for dimensionality reduction and batch effect removal for scRNA-seq data. It is designed to be massively parallelizable using shared objects that prevent memory duplication, and it can be used with different mini-batch approaches in order to reduce time consumption. It assumes a negative binomial distribution for the data with a dispersion parameter that can be both commonwise across gene both genewise.

**Depends** R (>= 4.0), SummarizedExperiment

**Imports** methods, SingleCellExperiment, parallel, irlba, Matrix, DelayedArray, BiocSingular, SharedObject, stats

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---

`delayed_initialization`*Initialize the parameters of a Negative Binomial regression model with a DelayedArray object*

---

**Description**

It initialize gamma and beta using a Ridge Regression and W and alpha using PCA

**Usage**

```
delayed_initialization(cluster, children, model, verbose, Y)
```

**Arguments**

|                       |                          |
|-----------------------|--------------------------|
| <code>cluster</code>  | The PSOCK cluster        |
| <code>children</code> | Number of child process. |
| <code>model</code>    | The newmodel object      |
| <code>verbose</code>  | Print proc time          |
| <code>Y</code>        | Is the data matrix       |

**Value**

It does not return anything, the parameters are update internally as these are shared object

---

`delayed_optimization` *Optimize the parameters of a Negative Binomial regression model with Delayed Array object*

---

**Description**

The parameters of the model given as argument are optimized by penalized maximum likelihood on the count matrix given as argument.

**Usage**

```
delayed_optimization(  
  Y,  
  cluster,  
  children,  
  model,  
  max_iter,  
  stop_epsilon,  
  n_gene_disp,
```

```

    n_cell_par,
    n_gene_par,
    commondispersion,
    verbose
  )

```

### Arguments

|                  |                                                                                                                     |
|------------------|---------------------------------------------------------------------------------------------------------------------|
| cluster          | The PSOCK cluster                                                                                                   |
| children         | Number of child process                                                                                             |
| model            | newmodel item                                                                                                       |
| max_iter         | maximum number of iterations                                                                                        |
| stop_epsilon     | stopping criterion, when the relative gain in likelihood is below epsilon                                           |
| n_gene_disp      | number of genes used in mini-batch dispersion estimation approach(default NULL > all genes are used)                |
| n_cell_par       | number of cells used in mini-batch cell's related parameters estimation approach(default NULL > all cells are used) |
| n_gene_par       | number of genes used in mini-batch gene's related parameters estimation approach(default NULL > all genes are used) |
| commondispersion | Whether or not a single dispersion for all features is estimated (default TRUE).                                    |
| verbose          | print information (default FALSE)                                                                                   |

### Value

An object of class newmodel similar to the one given as argument with modified parameters alpha, beta, gamma, W.

---

|                |                                                                          |
|----------------|--------------------------------------------------------------------------|
| initialization | <i>Initialize the parameters of a Negative Binomial regression model</i> |
|----------------|--------------------------------------------------------------------------|

---

### Description

It initialize gamma and beta using a Ridge Regression and W and alpha using PCA

### Usage

```
initialization(cluster, children, model, verbose, Y)
```

### Arguments

|          |                          |
|----------|--------------------------|
| cluster  | The PSOCK cluster        |
| children | Number of child process. |
| model    | The newmodel object      |
| verbose  | Print proc time          |

**Value**

It does not return anything, the parameters are update internally as these are shared object

---

|                  |                                                                                             |
|------------------|---------------------------------------------------------------------------------------------|
| nb.loglik.matrix | <i>Log-likelihood of the negative binomial model for each entry in the matrix of counts</i> |
|------------------|---------------------------------------------------------------------------------------------|

---

**Description**

Given a matrix of counts, this function computes the log-probabilities of the counts under a zero-inflated negative binomial (NB) model. For each count, the NB distribution is parametrized by two parameters: the mean value and the dispersion of the negative binomial distribution.

**Usage**

```
nb.loglik.matrix(model, x)
```

**Arguments**

|       |                      |
|-------|----------------------|
| model | the newmodel         |
| x     | the matrix of counts |

**Value**

the matrix of log-likelihood of the model.

---

|        |                                                   |
|--------|---------------------------------------------------|
| newAIC | <i>Compute the AIC of a model given some data</i> |
|--------|---------------------------------------------------|

---

**Description**

Given a statistical model and some data, this function computes the AIC of the model given the data, i.e., the AIC of the data under the model.

**Usage**

```
newAIC(model, x)

## S4 method for signature 'newmodel,matrix'
newAIC(model, x)
```

**Arguments**

|       |                                               |
|-------|-----------------------------------------------|
| model | an object that describes a statistical model. |
| x     | an object that describes data.                |

**Value**

the AIC of the model.

**Functions**

- `newAIC,newmodel,matrix-method`: returns the AIC of the NB model.

**Examples**

```
m <- newmodel(n=5, J=10)
x <- newSim(m)
newAIC(m, x$counts)
```

---

newAlpha

*Returns the matrix of paramters alpha*

---

**Description**

Given an object that describes a matrix of negative binomial distributions, returns the matrix of parameters associated with W for the mean part ( $\mu$ )

**Usage**

```
newAlpha(object, ...)
```

**Arguments**

`object`            an object that describes a matrix of negative binomial distributions.  
`...`                Additional parameters.

**Value**

the matrix of alpha parameters

**Examples**

```
a <- newmodel(n=5, J=10)
newAlpha(a)
```

---

|         |                                      |
|---------|--------------------------------------|
| newBeta | Returns the matrix of paramters beta |
|---------|--------------------------------------|

---

**Description**

Given an object that describes a matrix of negative binomial distributions, returns the matrix of parameters associated with X

**Usage**

```
newBeta(object, ...)
```

**Arguments**

|        |                                                                       |
|--------|-----------------------------------------------------------------------|
| object | an object that describes a matrix of negative binomial distributions. |
| ...    | Additional parameters.                                                |

**Value**

the matrix of beta parameters

**Examples**

```
a <- newmodel(n=5, J=10)
newBeta(a)
```

---

|        |                                            |
|--------|--------------------------------------------|
| newBIC | Compute the BIC of a model given some data |
|--------|--------------------------------------------|

---

**Description**

Given a statistical model and some data, this function computes the BIC of the model given the data, i.e., the BIC of the data under the model.

**Usage**

```
newBIC(model, x)

## S4 method for signature 'newmodel,matrix'
newBIC(model, x)
```

**Arguments**

|       |                                               |
|-------|-----------------------------------------------|
| model | an object that describes a statistical model. |
| x     | an object that describes data.                |

**Value**

the BIC of the model.

**Functions**

- newBIC,newmodel,matrix-method: returns the BIC of the NB model.

**Examples**

```
m <- newmodel(n=5, J=10)
x <- newSim(m)
newBIC(m, x$counts)
```

---

|                  |                                                                 |
|------------------|-----------------------------------------------------------------|
| newEpsilon_alpha | <i>Returns the vector of regularization parameter for alpha</i> |
|------------------|-----------------------------------------------------------------|

---

**Description**

Given an object describing a nb model, returns a vector of size the number of rows in the parameter alpha with the regularization parameters associated to each row.

**Usage**

```
newEpsilon_alpha(object)
```

**Arguments**

object            an object that describes a matrix of negative binomial distributions.

**Value**

the regularization parameters for alpha.

**Examples**

```
a <- newmodel(n=5, J=10)
newEpsilon_alpha(a)
```



---

|                 |                                                         |
|-----------------|---------------------------------------------------------|
| newEpsilon_beta | Returns the vector of regularization parameter for beta |
|-----------------|---------------------------------------------------------|

---

**Description**

Given an object describing a nb model, returns a vector of size the number of rows in the parameter beta with the regularization parameters associated to each row.

**Usage**

```
newEpsilon_beta(object)
```

**Arguments**

object            an object that describes a matrix of negative binomial distributions.

**Value**

the regularization parameters for beta.

**Examples**

```
a <- newmodel(n=5, J=10)
newEpsilon_beta(a)
```

---

|                  |                                                          |
|------------------|----------------------------------------------------------|
| newEpsilon_gamma | Returns the vector of regularization parameter for gamma |
|------------------|----------------------------------------------------------|

---

**Description**

Given an object describing a nb model, returns a vector of size the number of columns in the parameter gamma with the regularization parameters associated to each row.

**Usage**

```
newEpsilon_gamma(object)
```

**Arguments**

object            an object that describes a matrix of negative binomial distributions.

**Value**

the regularization parameters for gamma.

**Examples**

```
a <- newmodel(n=5, J=10)
newEpsilon_gamma(a)
```

---

|              |                                                             |
|--------------|-------------------------------------------------------------|
| newEpsilon_W | <i>Returns the vector of regularization parameter for W</i> |
|--------------|-------------------------------------------------------------|

---

**Description**

Given an object describing a nb model, returns a vector of size the number of columns in the parameter W with the regularization parameters associated to each column.

**Usage**

```
newEpsilon_W(object)
```

**Arguments**

object                    an object that describes a matrix of negative binomial distributions.

**Value**

the regularization parameters for W.

**Examples**

```
a <- newmodel(n=5, J=10)
newEpsilon_W(a)
```

---

|                 |                                                                          |
|-----------------|--------------------------------------------------------------------------|
| newEpsilon_zeta | <i>Returns the regularization parameter for the dispersion parameter</i> |
|-----------------|--------------------------------------------------------------------------|

---

**Description**

The regularization parameter penalizes the variance of zeta, the log of the dispersion parameters across samples.

**Usage**

```
newEpsilon_zeta(object)
```

**Arguments**

object                    an object that describes a matrix of negative binomial distributions.

**Value**

the regularization parameters for zeta.

**Examples**

```
a <- newmodel(n=5, J=10)
newEpsilon_zeta(a)
```

---

`newFit`*Fit a nb regression model*

---

**Description**

Given an object with the data, it fits a nb model.

**Usage**

```
newFit(Y, ...)

## S4 method for signature 'SummarizedExperiment'
newFit(
  Y,
  X,
  V,
  K = 2,
  which_assay,
  commondispersion = TRUE,
  verbose = FALSE,
  maxiter_optimize = 100,
  stop_epsilon = 1e-04,
  children = 1,
  random_init = FALSE,
  random_start = FALSE,
  n_gene_disp = NULL,
  n_cell_par = NULL,
  n_gene_par = NULL,
  ...
)

## S4 method for signature 'matrix'
newFit(
  Y,
  X,
  V,
  K = 2,
  commondispersion = TRUE,
  verbose = FALSE,
  maxiter_optimize = 100,
  stop_epsilon = 1e-04,
  children = 1,
  random_init = FALSE,
  random_start = FALSE,
  n_gene_disp = NULL,
  n_cell_par = NULL,
  n_gene_par = NULL,
```

```

    ...
)

## S4 method for signature 'DelayedMatrix'
newFit(
  Y,
  X,
  V,
  K = 2,
  commondispersion = TRUE,
  verbose = FALSE,
  maxiter_optimize = 100,
  stop_epsilon = 1e-04,
  children = 1,
  random_init = FALSE,
  random_start = FALSE,
  n_gene_disp = NULL,
  n_cell_par = NULL,
  n_gene_par = NULL,
  ...
)

## S4 method for signature 'dgCMatrix'
newFit(Y, ...)
```

## Arguments

|                  |                                                                                                                                                        |
|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| Y                | The matrix with the data                                                                                                                               |
| ...              | Additional parameters to describe the model, see <a href="#">newmodel</a> .                                                                            |
| X                | The design matrix containing sample-level covariates, one sample per row. If missing, X will contain only an intercept.                                |
| V                | The design matrix containing gene-level covariates, one gene per row. If missing, V will contain only an intercept.                                    |
| K                | integer. Number of latent factors(default 2).                                                                                                          |
| which_assay      | numeric or character. Which assay of Y to use. If missing, if 'assayNames(Y)' contains "counts" then that is used. Otherwise, the first assay is used. |
| commondispersion | Whether or not a single dispersion for all features is estimated (default TRUE).                                                                       |
| verbose          | Print helpful messages(default FALSE).                                                                                                                 |
| maxiter_optimize | maximum number of iterations for the optimization step (default 100).                                                                                  |
| stop_epsilon     | stopping criterion in the optimization step, when the relative gain in likelihood is below epsilon (default 0.0001).                                   |
| children         | number of cores of the used cluster(default 1)                                                                                                         |
| random_init      | if TRUE no initializations is done(default FALSE)                                                                                                      |

|              |                                                                                                                     |
|--------------|---------------------------------------------------------------------------------------------------------------------|
| random_start | if TRUE the setup of parameters is a random samplig(default FALSE)                                                  |
| n_gene_disp  | number of genes used in mini-batch dispersion estimation approach(default NULL > all genes are used)                |
| n_cell_par   | number of cells used in mini-batch cell's related parameters estimation approach(default NULL > all cells are used) |
| n_gene_par   | number of genes used in mini-batch gene's related parameters estimation approach(default NULL > all genes are used) |

## Details

By default, i.e., if no arguments other than Y are passed, the model is fitted with an intercept for the regression across-samples and one intercept for the regression across genes.

If Y is a Summarized experiment, the function uses the assay named "counts", if any, or the first assay.

Currently, if Y is a sparseMatrix, this calls the newFit method on as.matrix(Y)

## Value

An object of class newmodel that has been fitted by penalized maximum likelihood on the data.

## Methods (by class)

- SummarizedExperiment: Y is a SummarizedExperiment.
- matrix: Y is a matrix of counts (genes in rows).
- DelayedMatrix: Y is a DeleyedMatrix of counts (genes in rows).
- dgCMatrix: Y is a sparse matrix of counts (genes in rows).

## See Also

[model.matrix.](#)

## Examples

```
se <- SummarizedExperiment(matrix(rpois(60, lambda=5), nrow=10, ncol=6),
                             colData = data.frame(bio = gl(2, 3)))

m <- newFit(se, X=model.matrix(~bio, data=colData(se)))
bio <- gl(2, 3)
m <- newFit(matrix(rpois(60, lambda=5), nrow=10, ncol=6),
             X=model.matrix(~bio))
```

---

|          |                                               |
|----------|-----------------------------------------------|
| newGamma | <i>Returns the matrix of parameters gamma</i> |
|----------|-----------------------------------------------|

---

### Description

Given an object that describes a matrix of negative binomial distributions, returns the matrix of parameters associated with V

### Usage

```
newGamma(object, ...)
```

### Arguments

|        |                                                                       |
|--------|-----------------------------------------------------------------------|
| object | an object that describes a matrix of negative binomial distributions. |
| ...    | Additional parameters.                                                |

### Value

the matrix of gamma parameters

### Examples

```
a <- newmodel(n=5, J=10)
newGamma(a)
```

---

|           |                                                              |
|-----------|--------------------------------------------------------------|
| newloglik | <i>Compute the log-likelihood of a model given some data</i> |
|-----------|--------------------------------------------------------------|

---

### Description

Given a statistical model and some data, this function computes the log-likelihood of the model given the data, i.e., the log-probability of the data under the model.

### Usage

```
newloglik(model, x, ...)

## S4 method for signature 'newmodel,matrix'
newloglik(model, x)
```

### Arguments

|       |                                               |
|-------|-----------------------------------------------|
| model | an object that describes a statistical model. |
| x     | an object that describes data.                |
| ...   | additional arguments.                         |

**Value**

The log-likelihood of the model given the data.

**Methods (by class)**

- `model = newmodel, x = matrix`: return the log-likelihood of the nb model.

**Examples**

```
m <- newmodel(n=5, J=10)
x <- newSim(m)
newloglik(m, x$counts)
```

---

newLogMu

*Returns the matrix of logarithm of mean parameters*


---

**Description**

Given an object that describes a matrix of negative binomial distributions, returns the matrix of logarithm of mean parameters.

**Usage**

```
newLogMu(object)
```

**Arguments**

`object`                      an object that describes a matrix of negative binomial distributions.

**Details**

Note that although the user interface of `newFit` requires a  $J \times n$  matrix, internally this is stored as a  $n \times J$  matrix (i.e., samples in row and genes in column). Hence the parameter matrix returned by this function is of  $n \times J$  dimensions.

**Value**

the matrix of logarithms of mean parameters

**Examples**

```
a <- newmodel(n=5, J=10)
newLogMu(a)
```

---

newmodel

Initialize an object of class newmodel

---

## Description

Initialize an object of class newmodel

## Usage

```
newmodel(
  X,
  V,
  W,
  beta,
  gamma,
  alpha,
  zeta,
  epsilon,
  epsilon_beta,
  epsilon_gamma,
  epsilon_W,
  epsilon_alpha,
  epsilon_zeta,
  n,
  J,
  K
)
```

## Arguments

|               |                                                                                   |
|---------------|-----------------------------------------------------------------------------------|
| X             | matrix. The design matrix containing sample-level covariates, one sample per row. |
| V             | matrix. The design matrix containing gene-level covariates, one gene per row.     |
| W             | matrix. The factors of sample-level latent factors.                               |
| beta          | matrix or NULL. The coefficients of X in the regression of mu.                    |
| gamma         | matrix or NULL. The coefficients of V in the regression of mu.                    |
| alpha         | matrix or NULL. The coefficients of W in the regression of mu.                    |
| zeta          | numeric. A vector of log of inverse dispersion parameters.                        |
| epsilon       | nonnegative scalar. Regularization parameter.                                     |
| epsilon_beta  | nonnegative scalar. Regularization parameter for beta.                            |
| epsilon_gamma | nonnegative scalar. Regularization parameter for gamma.                           |
| epsilon_W     | nonnegative scalar. Regularization parameter for W.                               |
| epsilon_alpha | nonnegative scalar. Regularization parameter for alpha                            |



|                           |                                                        |
|---------------------------|--------------------------------------------------------|
| <code>epsilon_zeta</code> | nonnegative scalar. Regularization parameter for zeta. |
| <code>n</code>            | integer. Number of samples.                            |
| <code>J</code>            | integer. Number of genes.                              |
| <code>K</code>            | integer. Number of latent factors.                     |

## Details

This is a wrapper around the `new()` function to create an instance of class `newmodel`. Rarely, the user will need to create a `newmodel` object from scratch, as typically this is the result of `newFit`.

If any of  $X$ ,  $V$ ,  $W$  matrices are passed,  $n$ ,  $J$ , and  $K$  are inferred. Alternatively, the user can specify one or more of  $n$ ,  $J$ , and  $K$ .

The regularization parameters can be set by a unique parameter `epsilon` or specific values for the different regularization parameters can also be provided. If only `epsilon` is specified, the other parameters take the following values:

- `epsilon_beta` = `epsilon/J`
- `epsilon_gamma` = `epsilon/n`
- `epsilon_W` = `epsilon/n`
- `epsilon_alpha` = `epsilon/J`
- `epsilon_zeta` = `epsilon`

We empirically found that large values of `epsilon` provide a more stable estimation of  $W$ .

A call with no argument has the following default values:  $n = 50$ ,  $J = 100$ ,  $K = 0$ , `epsilon`= $J$ .

Although it is possible to create new instances of the class by calling this function, this is not the most common way of creating `newmodel` objects. The main use of the class is within the `newFit` function.

## Value

an object of class `newmodel`.

## Examples

```
a <- newmodel()
numberSamples(a)
numberFeatures(a)
numberFactors(a)
```

---

`newmodel-class`*Class newmodel*

---

**Description**

Objects of this class store all the values needed to work with a negative binomial model, as described in the vignette. They contain all information to fit a model by penalized maximum likelihood or simulate data from a model.

**Usage**

```
## S4 method for signature 'newmodel'  
show(object)
```

```
## S4 method for signature 'newmodel'  
numberSamples(x)
```

```
## S4 method for signature 'newmodel'  
numberFeatures(x)
```

```
## S4 method for signature 'newmodel'  
numberFactors(x)
```

```
## S4 method for signature 'newmodel'  
newX(object)
```

```
## S4 method for signature 'newmodel'  
newV(object)
```

```
## S4 method for signature 'newmodel'  
newLogMu(object)
```

```
## S4 method for signature 'newmodel'  
newMu(object)
```

```
## S4 method for signature 'newmodel'  
newZeta(object)
```

```
## S4 method for signature 'newmodel'  
newPhi(object)
```

```
## S4 method for signature 'newmodel'  
newTheta(object)
```

```
## S4 method for signature 'newmodel'  
newEpsilon_beta(object)
```

```
## S4 method for signature 'newmodel'
newEpsilon_gamma(object)

## S4 method for signature 'newmodel'
newEpsilon_W(object)

## S4 method for signature 'newmodel'
newEpsilon_alpha(object)

## S4 method for signature 'newmodel'
newEpsilon_zeta(object)

## S4 method for signature 'newmodel'
newW(object)

## S4 method for signature 'newmodel'
newBeta(object)

## S4 method for signature 'newmodel'
newGamma(object)

## S4 method for signature 'newmodel'
newAlpha(object)
```

### Arguments

|        |                              |
|--------|------------------------------|
| object | an object of class newmodel. |
| x      | an object of class newmodel. |

### Details

For the full description of the model see the model vignette. Internally, the slots are checked so that the matrices are of the appropriate dimensions: in particular, X, O and W need to have n rows, V needs to have J rows, zeta must be of length J.

### Value

numberSamples returns the number of samples; numberFeatures returns the number of features; numberFactors returns the number of latent factors.

### Methods (by generic)

- show: show useful info on the object.
- numberSamples: returns the number of samples.
- numberFeatures: returns the number of features.
- numberFactors: returns the number of latent factors.
- newX: returns the sample-level design matrix for mu.
- newV: returns the gene-level design matrix for mu.

- newLogMu: returns the logarithm of the mean of the non-zero component.
- newMu: returns the mean of the non-zero component.
- newZeta: returns the log of the inverse of the dispersion parameter.
- newPhi: returns the dispersion parameter.
- newTheta: returns the inverse of the dispersion parameter.
- newEpsilon\_beta: returns the regularization parameters for beta.
- newEpsilon\_gamma: returns the regularization parameters for gamma.
- newEpsilon\_W: returns the regularization parameters for W.
- newEpsilon\_alpha: returns the regularization parameters for alpha.
- newEpsilon\_zeta: returns the regularization parameters for zeta.
- newW: returns the matrix W of inferred sample-level covariates.
- newBeta: returns the matrix beta of inferred parameters.
- newGamma: returns the matrix gamma of inferred parameters.
- newAlpha: returns the matrix alpha of inferred parameters.

## Slots

**X** matrix. The design matrix containing sample-level covariates, one sample per row.

**V** matrix. The design matrix containing gene-level covariates, one gene per row.

**X\_intercept** logical. TRUE if X contains an intercept.

**V\_intercept** logical. TRUE if V contains an intercept.

**W** matrix. The factors of sample-level latent factors.

**beta** matrix or NULL. The coefficients of X in the regression.

**gamma** matrix or NULL. The coefficients of V in the regression.

**alpha** matrix. The weight of sample-level latent factors.

**zeta** numeric. A vector of log of inverse dispersion parameters.

**epsilon\_beta** nonnegative scalar. Regularization parameter for beta

**epsilon\_gamma** nonnegative scalar. Regularization parameter for gamma

**epsilon\_W** nonnegative scalar. Regularization parameter for W

**epsilon\_alpha** nonnegative scalar. Regularization parameter for alpha

**epsilon\_zeta** nonnegative scalar. Regularization parameter for zeta

---

|       |                                              |
|-------|----------------------------------------------|
| newMu | <i>Returns the matrix of mean parameters</i> |
|-------|----------------------------------------------|

---

### Description

Given an object that describes a matrix of negative binomial distributions, returns the matrix of mean parameters.

### Usage

```
newMu(object)
```

### Arguments

`object`                      an object that describes a matrix of negative binomial distributions.

### Details

Note that although the user interface of `newFit` requires a  $J \times n$  matrix, internally this is stored as a  $n \times J$  matrix (i.e., samples in row and genes in column). Hence the parameter matrix returned by this function is of  $n \times J$  dimensions.

### Value

the matrix of mean parameters

### Examples

```
a <- newmodel(n=5, J=10)
newMu(a)
```

---

|            |                                       |
|------------|---------------------------------------|
| newpenalty | <i>Compute the penalty of a model</i> |
|------------|---------------------------------------|

---

### Description

Given a statistical model with regularization parameters, compute the penalty.

### Usage

```
newpenalty(model)
```

```
## S4 method for signature 'newmodel'
newpenalty(model)
```

**Arguments**

`model` an object that describes a statistical model with regularization parameters.

**Value**

The penalty of the model.

**Methods (by class)**

- `newmodel`: return the penalization.

**Examples**

```
m <- newmodel(K=2)
newpenalty(m)
```

---

|                     |                                                    |
|---------------------|----------------------------------------------------|
| <code>newPhi</code> | <i>Returns the vector of dispersion parameters</i> |
|---------------------|----------------------------------------------------|

---

**Description**

Given an object that describes a matrix of negative binomial negative binomial distributions, returns the vector of dispersion parameters `phi`.

**Usage**

```
newPhi(object)
```

**Arguments**

`object` an object that describes a matrix of negative binomial. distributions.

**Value**

the vector of dispersion parameters

**Examples**

```
a <- newmodel(n=5, J=10)
newPhi(a)
```

---

newSim

*Simulate counts from a negative binomial model*


---

## Description

Given an object that describes negative binomial distribution, simulate counts from the distribution.

## Usage

```
newSim(object, seed, ...)

## S4 method for signature 'newmodel'
newSim(object, seed)
```

## Arguments

|        |                                                                                                                                                                                    |
|--------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| object | an object that describes a matrix of negative binomial.                                                                                                                            |
| seed   | an optional integer to specify how the random number generator should be initialized with a call to <code>set.seed</code> . If missing, the random generator state is not changed. |
| ...    | additional arguments.                                                                                                                                                              |

## Value

A list with the following elements.

- `counts` the matrix with the simulated counts.
- `dataNB` the data simulated from the negative binomial.
- `dataDropout` the data simulated from the binomial process.
- `zeroFraction` the fraction of zeros.

## Methods (by class)

- `newmodel`: simulate from a nb distribution.

## Examples

```
a <- newmodel(n=5, J=10)
newSim(a)
```

---

|          |                                                            |
|----------|------------------------------------------------------------|
| newTheta | <i>Returns the vector of inverse dispersion parameters</i> |
|----------|------------------------------------------------------------|

---

### Description

Given an object that describes a matrix of negative binomial negative binomial distributions, returns the vector of inverse dispersion parameters theta.

### Usage

```
newTheta(object)
```

### Arguments

object            an object that describes a matrix of negative binomial distributions.

### Value

the vector of inverse dispersion parameters theta

### Examples

```
a <- newmodel(n=5, J=10)
newTheta(a)
```

---

|      |                                                    |
|------|----------------------------------------------------|
| newV | <i>Returns the gene-level design matrix for mu</i> |
|------|----------------------------------------------------|

---

### Description

Given an object that describes a matrix of negative binomial distributions, returns the gene-level design matrix for mu

### Usage

```
newV(object, ...)
```

### Arguments

object            an object that describes a matrix of negative binomial distributions.  
 ...               Additional parameters.

### Value

the gene-level design matrix for mu



**Examples**

```
a <- newmodel(n=5, J=10)
newV(a)
```

---

|      |                                                                                 |
|------|---------------------------------------------------------------------------------|
| newW | <i>Returns the low-dimensional matrix of inferred sample-level covariates W</i> |
|------|---------------------------------------------------------------------------------|

---

**Description**

Given an object that contains the fit of a nb-WaVE model, returns the matrix W of low-dimensional matrix of inferred sample-level covariates.

**Usage**

```
newW(object)
```

**Arguments**

object            a `newmodel` object, typically the result of `newFit`.

**Value**

the matrix W of inferred sample-level covariates.

**Examples**

```
a <- newmodel(n=5, J=10)
newW(a)
```

---

|         |                                                                                                          |
|---------|----------------------------------------------------------------------------------------------------------|
| newWave | <i>Perform dimensionality reduction using a nb regression model with gene and cell-level covariates.</i> |
|---------|----------------------------------------------------------------------------------------------------------|

---

**Description**

Given an object with the data, it performs dimensionality reduction using a nb regression model with gene and cell-level covariates.

**Usage**

```
newWave(Y, ...)

## S4 method for signature 'SummarizedExperiment'
newWave(
  Y,
  X,
  V,
  K = 2,
  which_assay,
  commondispersion = TRUE,
  verbose = FALSE,
  maxiter_optimize = 100,
  stop_epsilon = 1e-04,
  children = 1,
  random_init = FALSE,
  random_start = FALSE,
  n_gene_disp = NULL,
  n_cell_par = NULL,
  n_gene_par = NULL,
  ...
)
```

**Arguments**

|                  |                                                                                                                                                                                                                                 |
|------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Y                | The SummarizedExperiment with the data                                                                                                                                                                                          |
| ...              | Additional parameters to describe the model, see <a href="#">newmodel1</a> .                                                                                                                                                    |
| X                | The design matrix containing sample-level covariates, one sample per row. If missing, X will contain only an intercept. If Y is a SummarizedExperiment object, X can be a formula using the variables in the colData slot of Y. |
| V                | The design matrix containing gene-level covariates, one gene per row. If missing, V will contain only an intercept. If Y is a SummarizedExperiment object, V can be a formula using the variables in the rowData slot of Y.     |
| K                | integer. Number of latent factors(default 2).                                                                                                                                                                                   |
| which_assay      | numeric or character. Which assay of Y to use. If missing, if 'assayNames(Y)' contains "counts" then that is used. Otherwise, the first assay is used.                                                                          |
| commondispersion | Whether or not a single dispersion for all features is estimated (default TRUE).                                                                                                                                                |
| verbose          | Print helpful messages(default FALSE).                                                                                                                                                                                          |
| maxiter_optimize | maximum number of iterations for the optimization step (default 100).                                                                                                                                                           |
| stop_epsilon     | stopping criterion in the optimization step, when the relative gain in likelihood is below epsilon (default 0.0001).                                                                                                            |
| children         | number of cores of the used cluster(default 1)                                                                                                                                                                                  |
| random_init      | if TRUE no initializations is done(default FALSE)                                                                                                                                                                               |

|                           |                                                                                                                    |
|---------------------------|--------------------------------------------------------------------------------------------------------------------|
| <code>random_start</code> | if TRUE the setup of parameters is a random samplig (default FALSE)                                                |
| <code>n_gene_disp</code>  | number of genes used in mini-batch dispersion estimation approach(default NULL > all genes are used)               |
| <code>n_cell_par</code>   | number of cells used in mini-batch cells related parameters estimation approach(default NULL > all cells are used) |
| <code>n_gene_par</code>   | number of genes used in mini-batch genes related parameters estimation approach(default NULL > all genes are used) |

## Details

For visualization (heatmaps, ...), please use the normalized values. It corresponds to the deviance residuals when the  $W$  is not included in the model but the gene and cell-level covariates are. As a results, when  $W$  is not included in the model, the deviance residuals should capture the biology. Note that we do not recommend to use the normalized values for any downstream analysis (such as clustering, or differential expression), but only for visualization.

If one has already fitted a model using `newmodel`, the object containing such model can be used as input of `newWave` to save the resulting  $W$  into a `SummarizedExperiment` and optionally compute residuals and normalized values, without the need for re-fitting the model.

By default `newWave` uses all genes to estimate  $W$ . However, we recommend to use the top 1,000 most variable genes for this step. In general, a user can specify any custom set of genes to be used to estimate  $W$ , by specifying either a vector of gene names, or a single character string corresponding to a column of the `rowData`.

Note that if both `which_genes` is specified and at least one among `observationalWeights`, `imputedValues`, `residuals`, and `normalizedValues` is TRUE, the model needs to be fit twice.

## Value

An object of class `SingleCellExperiment`; the dimensionality reduced matrix is stored in the `reducedDims` slot and optionally normalized values and residuals are added in the list of assays.

## Methods (by class)

- `SummarizedExperiment`:  $Y$  is a `SummarizedExperiment`.

## Examples

```
se <- SummarizedExperiment(matrix(rpois(60, lambda=5), nrow=10, ncol=6),
                             colData = data.frame(bio = gl(2, 3)))

m <- newWave(se, X="~bio")
```

---

|      |                                                      |
|------|------------------------------------------------------|
| newX | <i>Returns the sample-level design matrix for mu</i> |
|------|------------------------------------------------------|

---

**Description**

Given an object that describes a matrix of negative binomial distributions, returns the sample-level design matrix for mu

**Usage**

```
newX(object, ...)
```

**Arguments**

|        |                                                                       |
|--------|-----------------------------------------------------------------------|
| object | an object that describes a matrix of negative binomial distributions. |
| ...    | Additional parameters.                                                |

**Value**

the sample-level design matrix for mu

**Examples**

```
a <- newmodel(n=5, J=10)
newX(a)
```

---

|         |                                                                   |
|---------|-------------------------------------------------------------------|
| newZeta | <i>Returns the vector of log of inverse dispersion parameters</i> |
|---------|-------------------------------------------------------------------|

---

**Description**

Given an object that describes a matrix of negative binomial negative binomial distributions, returns the vector zeta of log of inverse dispersion parameters

**Usage**

```
newZeta(object)
```

**Arguments**

|        |                                                                       |
|--------|-----------------------------------------------------------------------|
| object | an object that describes a matrix of negative binomial distributions. |
|--------|-----------------------------------------------------------------------|

**Value**

the vector zeta of log of inverse dispersion parameters

**Examples**

```
a <- newmodel(n=5, J=10)
newZeta(a)
```

---

**numberFactors***Generic function that returns the number of latent factors*

---

**Description**

Given an object that describes a dataset or a model involving latent factors, this function returns the number of latent factors.

**Usage**

```
numberFactors(x)
```

**Arguments**

**x** an object that describes a dataset or a model involving latent factors

**Value**

the number of latent factors

**Examples**

```
a <- newmodel(n=5, J=10)
numberFactors(a)
```

---

**numberFeatures***Generic function that returns the number of features*

---

**Description**

Given an object that describes a dataset or a model involving features, this function returns the number of features

Given an object that describes a dataset or a model, it returns the number of features.

**Usage**

```
numberFeatures(x)
```

```
numberFeatures(x)
```

**Arguments**

`x` an object that describes a dataset or a model.

**Value**

the number of features

the number of features.

**Examples**

```
a <- newmodel(n=5, J=10)
numberFeatures(a)
a <- newmodel(n=5, J=10)
numberFeatures(a)
```

---

|              |                                                                                  |
|--------------|----------------------------------------------------------------------------------|
| numberParams | <i>Generic function that returns the total number of parameters of the model</i> |
|--------------|----------------------------------------------------------------------------------|

---

**Description**

Given an object that describes a model or a dataset, it returns total number of parameters of the model.

**Usage**

```
numberParams(model)

## S4 method for signature 'newmodel'
numberParams(model)
```

**Arguments**

`model` an object that describes a dataset or a model.

**Value**

the total number of parameters of the model.

**Functions**

- `numberParams, newmodel-method`: returns the total number of parameters in the model.

**Examples**

```
a <- newmodel(n=5, J=10)
numberParams(a)
```

---

|               |                                                            |
|---------------|------------------------------------------------------------|
| numberSamples | <i>Generic function that returns the number of samples</i> |
|---------------|------------------------------------------------------------|

---

**Description**

Given an object that describes a dataset or a model involving samples, this function returns the number of samples.

Given an object that describes a model or a dataset, it returns the number of samples.

**Usage**

```
numberSamples(x)
```

```
numberSamples(x)
```

**Arguments**

x                      an object that describes a dataset or a model.

**Value**

the number of samples

the number of samples.

**Examples**

```
a <- newmodel(n=5, J=10)
numberSamples(a)
a <- newmodel(n=5, J=10)
numberSamples(a)
```

---

|              |                                                                        |
|--------------|------------------------------------------------------------------------|
| optimization | <i>Optimize the parameters of a Negative Binomial regression model</i> |
|--------------|------------------------------------------------------------------------|

---

**Description**

The parameters of the model given as argument are optimized by penalized maximum likelihood on the count matrix given as argument.

**Usage**

```
optimization(
  Y,
  cluster,
  children,
  model,
  max_iter,
  stop_epsilon,
  n_gene_disp,
  n_cell_par,
  n_gene_par,
  commondispersion,
  verbose
)
```

**Arguments**

|                  |                                                                                                                     |
|------------------|---------------------------------------------------------------------------------------------------------------------|
| cluster          | The PSOCK cluster                                                                                                   |
| children         | Number of child process                                                                                             |
| model            | newmodel item                                                                                                       |
| max_iter         | maximum number of iterations                                                                                        |
| stop_epsilon     | stopping criterion, when the relative gain in likelihood is below epsilon                                           |
| n_gene_disp      | number of genes used in mini-batch dispersion estimation approach(default NULL > all genes are used)                |
| n_cell_par       | number of cells used in mini-batch cell's related parameters estimation approach(default NULL > all cells are used) |
| n_gene_par       | number of genes used in mini-batch gene's related parameters estimation approach(default NULL > all genes are used) |
| commondispersion | Whether or not a single dispersion for all features is estimated (default TRUE).                                    |
| verbose          | print information (default FALSE)                                                                                   |

**Value**

An object of class newmodel similar to the one given as argument with modified parameters alpha, beta, gamma, W.

---

 setup

*Setup the parameters of a Negative Binomial regression model There are different type of starting values: 1.You can set all values to 0. 2.You can sample values from a gaussian distribution or a chisq distribution for the dispersion parameters,*

---



**Description**

It creates different shared object and export them to the father and the child process.

**Usage**

```
setup(cluster, model, random_start, children, random_init, verbose, Y_sh)
```

**Arguments**

|              |                                                                     |
|--------------|---------------------------------------------------------------------|
| cluster      | the PSOCK cluster object                                            |
| model        | The model of class newmodel                                         |
| random_start | if TRUE the setup of parameters is a random sampling(default FALSE) |
| children     | Number of child process.                                            |
| random_init  | if TRUE no initializations is done(default FALSE)                   |
| verbose      | Print helpful messages(default FALSE).                              |
| Y            | matrix of counts                                                    |

**Value**

A object of class newModel

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