Package 'NNMoMo'

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Type Package

Title Neural Network Extension to 'StMoMo' for Lee-Carter Modeling

Version 0.1.0

Description Provides extensions to the 'StMoMo' package by incorporating neural network functionality for Lee-Carter and Poisson Lee-Carter mortality models. Includes tools for constructing mortality datasets from 'demogdata' objects and fitting neural network-based mortality models. Further analysis, such as plotting and forecasting, can be done with 'StMoMo' functions.

License GPL-3

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Contents

`fit.NNMoMo` *Fit a Neural Network Lee-Carter Model*

Description

Fit a neural network mortality model based on prepared `NNMoMo` and `NNMoMoData` objects. The function allows selection of specific ages and years for fitting, restriction to particular series (female", "male" or "both"), and control of the training epochs. The model is trained using `torch` and `luz` and returns a list of `fitStMoMo`-like objects.

Usage

```
## S3 method for class 'NNMoMo'
fit(
  object,
  data,
  ages.fit = NULL,
  years.fit = NULL,
  series = c("both", "female", "male"),
  fitting.epochs = 2000,
  batch.size = 128,
  ...
)
```

Arguments

`object`	An object of class `NNMoMo` specifying the model structure (e.g., embedding dimension, model type, activation function, loss function). For more information see `lcNN`.
`data`	An object of class `NNMoMoData` containing mortality rates, population size, and relevant demographic features. See `NNMoMoData` for details.
`ages.fit`	Optional numeric vector specifying which ages to include in the fitting process. By default, all available ages are used.
`years.fit`	Optional numeric vector specifying which years to include in the fitting process. By default, all available years are used.

`series`	Indicates whether to fit the model for "female", "male" or "both". Default and recommended is "both".
`fitting.epochs`	Positive integer specifying the number of training epochs for the neural network. Values much lower than 2000 are not recommended.
`batch.size`	Positive integer specifying the batch size when training the model. A batch size of 128 is recommended as it was found to work the smoothest.
`...`	Arguments to be passed to or from other methods.

Details

Missing or zero values in the mortality rates are imputed using the average value at a certain age across all countries for that gender in that year. Data are processed for each combination of year and sex. Categorical variables such as country and sex are embedded via embedding layers.

Value

An object of class `fitNNMoMo`, where each element is a `fitStMoMo`-like object containing the estimated parameters a_x, b_x, k_t, the underlying data, and other metadata from the model fitting. These objects can be further used with functions from the **StMoMo** package for analysis, plotting, or extracting fitted mortality rates and exposures.

Examples

```
if (torch::torch_is_installed()) {
  # Example: fitting with random data, do not expect to get
  # any meaningful results.

  # creating example data for fitting:
  demography_obj <- demography::demogdata(
    data = matrix(runif(10*5), nrow = 10),
    pop = matrix(runif(10*5, 1000, 2000), nrow = 10),
    ages = 50:59,
    years = 2000:2004,
    type = "mortality",
    name = "male",
    label = "France"
  )
  nn_data <- NNMoMoData(demography_obj)

  # fitting the data in 10 epochs (in practice, many more epochs are needed):
  fit <- fit(object = lcNN(),
             data = nn_data,
             fitting.epochs = 10)

  plot(fit$France_male)
}
```

lcNN *Create a Lee-Carter Model with a Neural Network*

Description

Utility function to initialize a NNMoMo object representing a neural network Lee-Carter model. Important settings of the neural network can be specified here.

Usage

```
lcNN(
  activation = c("linear", "tanh", "relu"),
  model_type = c("FCN", "LCN", "CNN"),
  loss_type = c("MSE", "Poisson"),
  q_e = 10,
  q_z1 = 10
)
```

Arguments

activation	Sets the activation function of the k_t-subnet of the neural network. The first activation function is set by this parameter, the second is linear by default. "tanh" defines a tangens hyperbolicus activation function, "relu" is a Rectified Linear Unit function and "linear" sets a linear activation function.
model_type	Defines the feed-forward architecture of the neural network. "FCN" sets a fully connected network for the first layer of the k_t-subnet, "CNN" sets a convolutional neural network layer for this subset and "LCN" defines a locally connected network layer (note that the "LCN" option has some stability issues and therefore the use of "FCN" or "CNN" is recommended).
loss_type	Defines the type of the loss function. As a default value, "MSE" (Mean Squared Error) is set. This function minimizes the squared difference between the observed and estimated mortality rates $m_{x,t}$. "Poisson" evaluates the likelihood of the observed deaths.
q_e	Sets the dimension of the embedding vectors for country and sex speratly. The dimension of the full embedding vector is hence 2*q_e. A value between 5 and 15 is recommended.
q_z1	Sets the dimension of the first layer of the k_t-subnet. A value between 5 and 50 is recommended.

Value

An object of class NNMoMo.

Examples

```
# Sets up the neural network with the recommended settings:
model_1 <- lcNN()

# Sets up a fully customized netural network:
model_2 <- lcNN(activation = "tanh",
                model_type = "CNN",
                loss_type = "Poisson",
                q_e = 5,
                q_z1 = 25)

# These models can be used for fitting.
```

---

logLik.fitNNMoMo *Log-Likelihood Method for Neural Network Mortality Models*

Description

Computes the log-likelihood for objects of class `fitNNMoMo`. As this method has yet not been implemented, an error will be returned.

Usage

```
## S3 method for class 'fitNNMoMo'
logLik(object, ...)
```

Arguments

`object`	An object of class `fitNNMoMo`.
`...`	Further arguments passed to or from other methods.

Value

No value is returned. The function always raises an error.

NNMoMoData *Create NNMoMoData Object from Demogdata Object or HMD Datasets*

Description

Utility function to construct an object of class `NNMoMoData` from one or multiple mortality datasets of class `demogdata`. Each dataset is converted into a tabular representation with mortality rates and population counts by age, sex, and year, suitable for fitting a neural network using `fit.NNMoMo`.

Usage

```
NNMoMoData(...)
```

Arguments

...	One or more objects of class demogdata. Each input must contain mortality rates and population data for both sexes ("female", "male"), structured as in the **demography** package. If no arguments are provided, the function will prompt the user for Human Mortality Database (HMD) login credentials (email and password) and automatically download a predefined list of countries using hmd.mx. The list of countries is the same used by Scognamiglio, S. (2022). Calibrating the Lee-Carter and the Poisson Lee-Carter models via neural networks. ASTIN Bulletin: The Journal of the IAA, 52(2), 519-561. Cambridge University Press. doi:10.1017/asb.2022.5

Details

This function converts the age-by-year matrices of mortality rates and populations into long-format rows, one row per sex-year combination. Each row stores the full vector of rates and populations across all ages.

If any input is not of class demogdata, the function stops with an error.

If no inputs are provided, the function connects to the Human Mortality Database (HMD) using user-supplied credentials and downloads a predefined set of countries (AUS, AUT, BEL, BGR, BLR, CAN, CHE, CZE, DEUTE, DEUTW, DNK, ESP, EST, FIN, FRATNP, GBRTENW, GBR_NIR, GBR_SCO, GRC, HUN, IRL, ISL, ISR, ITA, JPN, LTU, LUX, LVA, NLD, NOR, NZL_NM, POL, PRT, RUS, SVK, SVN, SWE, TWN, UKR, USA). It might take a few minutes to download all of them.

A demogdata object can also be created from scratch or imported manually from the Human Mortality Database using hmd.mx.

The label of the demogdata object must be specified, as all subsequent operations rely on this label.

Value

An object of class NNMoMoData containing the following columns:

- country: Country label from the input demogdata object.
- sex: Sex of the population ("female" or "male").
- year: Calendar year.
- rate_*: Mortality rates by age (e.g., rate_0, rate_1, ...).
- pop_*: Population counts by age (e.g., pop_0, pop_1, ...).

Examples

```
# Example 1: Create from an existing demogdata object
demography_obj <- demography::demogdata(
  data = matrix(runif(10*5), nrow = 10),
  pop = matrix(runif(10*5, 1000, 2000), nrow = 10),
```

```
  ages = 50:59,
  years = 2000:2004,
  type = "mortality",
  name = "male",
  label = "France"
)
nn_data <- NNMoMoData(demography_obj)
head(nn_data)

## Not run:
# Example 2: Automatic download from HMD if no arguments are provided
# (will prompt for email and password, requires HMD access)
nn_data_auto <- NNMoMoData()
head(nn_data_auto)

## End(Not run)
```

NNMoMo_data_AUS *Australia Dataset*

Description

Example dataset for Australia. Provided with the **NNMoMo** package.

Usage

```
NNMoMo_data_AUS
```

Format

An object of class demogdata of length 7.

Details

Data obtained with `demography::hmd.mx()` about Australia. Downloaded in September 2025.

Source

NNMoMo package

NNMoMo_data_CAN *Canada Dataset*

Description

Example dataset for Canada. Provided with the **NNMoMo** package.

Usage

```
NNMoMo_data_CAN
```

Format

An object of class `demogdata` of length 7.

Details

Data obtained with `demography::hmd.mx()` about Canada. Downloaded in September 2025.

Source

NNMoMo package

NNMoMo_data_GBR *United Kingdom Dataset*

Description

Example dataset for the United Kingdom. Provided with the **NNMoMo** package.

Usage

```
NNMoMo_data_GBR
```

Format

An object of class `demogdata` of length 7.

Details

Data obtained with `demography::hmd.mx()` about the United Kingdom. Downloaded in September 2025.

Source

NNMoMo package

NNMoMo_data_JPN *Japan Dataset*

Description

Example dataset for Japan. Provided with the **NNMoMo** package.

Usage

```
NNMoMo_data_JPN
```

Format

An object of class `demogdata` of length 7.

Details

Data obtained with `demography::hmd.mx()` about Japan. Downloaded in September 2025.

Source

NNMoMo package

NNMoMo_data_USA *USA Dataset*

Description

Example dataset for the United States. Provided with the **NNMoMo** package.

Usage

```
NNMoMo_data_USA
```

Format

An object of class `demogdata` of length 7.

Details

Data obtained with `demography::hmd.mx()` about the USA. Downloaded in September 2025.

Source

NNMoMo package

print.fitStMoMo_list *Print Method for the Output of the Fitting Method*

Description

Method for printing the output of the fitting method. Gives fundamental infofmation about the object.

Usage

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

Arguments

x	An object of class fitStMoMo_list.
...	Further arguments passed to or from other methods.

Value

Prints basic information about the fitStMoMo_list object to the console.

print.NNMoMo *Print Method for NNMoMo Objects*

Description

Method for printing the output of lcNN. Gives fundamental infofmation about the object.

Usage

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

Arguments

x	An object of class NNMoMo.
...	Further arguments passed to or from other methods.

Value

Prints basic information about the NNMoMo object to the console.

print.NNMoMoData *Print Method for NNMoMoData Objects*

Description

Method for printing the output of NNMoMoData. Gives fundamental infofmation about the object.

Usage

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

Arguments

x	An object of class NNMoMoData.
...	Further arguments passed to or from other methods.

Value

Prints basic information about the NNMoMoData object to the console.

residuals.fitNNMoMo *Compute Residuals for NNMoMo Fitted Models*

Description

This function computes the residuals for objects created by fit.NNMoMo. It is analog to the residuals.fitStMoMo function for **StMoMo** but without the option to scale the residuals as nobs and npar are not provided by the neural network.

Usage

```
## S3 method for class 'fitNNMoMo'
residuals(object, scale = FALSE, ...)
```

Arguments

object	An object of class fitNNMoMo with the fitted parameters of a stochastic mortality model.
scale	Logical, default FALSE. If TRUE, an error is thrown because the number of observations (nobs) and parameters (npar) cannot be calculated for fitNNMoMo objects.
...	Further arguments passed to or from other methods.

Value

An object of class `resStMoMo` with the residuals. This object has components:

- `residuals`: a matrix with the residuals.
- `ages`: ages corresponding to the rows in `residuals`.
- `years`: years corresponding to the columns in `residuals`.

---

summary.fitStMoMo_list *Summary Method for the Output of the Fitting Method*

Description

Method for printing the summary of the fitting method. Gives detailed infofmation about the object.

Usage

```
## S3 method for class 'fitStMoMo_list'
summary(object, ...)
```

Arguments

`object`	An object of class `fitStMoMo_list`.
`...`	Further arguments passed to or from other methods.

Value

Displays a summary of the `fitStMoMo_list` object in the console.

---

summary.NNMoMo *Summary Method for NNMoMo Objects*

Description

Method for printing the summary of `lcNN`. Gives detailed infofmation about the object.

Usage

```
## S3 method for class 'NNMoMo'
summary(object, ...)
```

Arguments

`object`	An object of class `NNMoMo`.
`...`	Further arguments passed to or from other methods.

Value

Displays a summary of the NNMoMo object in the console.

`summary.NNMoMoData` *Summary Method for NNMoMoData Objects*

Description

Method for printing the summary of NNMoMoData. Gives detailed infofmation about the object.

Usage

```
## S3 method for class 'NNMoMoData'
summary(object, ...)
```

Arguments

object	An object of class NNMoMoData.
...	Further arguments passed to or from other methods.

Value

Displays a summary of the NNMoMoData object in the console.

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