

Package ‘echos’

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Type Package

Title Echo State Networks for Time Series Modeling and Forecasting

Version 1.0.2

Description Provides a lightweight implementation of functions and methods for fast and fully automatic time series modeling and forecasting using Echo State Networks (ESNs).

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URL <https://github.com/ahaeusser/echos>,
<https://ahaeusser.github.io/echos/>

BugReports <https://github.com/ahaeusser/echos/issues>

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ESN	<i>Train an Echo State Network</i>
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Description

Train an Echo State Network (ESN) to a univariate time series. The function automatically manages data pre-processing, reservoir generation (i.e., internal states) and model estimation and selection. The function is a wrapper for `train_esn()` and intended to be used in combination with `fabletools::model()`.

Usage

```
ESN(formula, ...)
```

Arguments

formula	Model specification (currently not in use).
...	Further arguments passed to <code>train_esn()</code> .

Value

An object of class ESN.

Examples

```
library(tsibble)
library(fable)
AirPassengers %>%
  as_tsibble() %>%
  model("ESN" = ESN(value))
```

filter_esn	<i>Filter ESN models</i>
------------	--------------------------

Description

Filter an object of class `mdl_df` ("mable") to include ESN models only, i.e., other models like ARIMA or ETS are excluded from the mable.

Usage

```
filter_esn(object)
```

Arguments

`object` An object of class `mdl_df`, containing an ESN model.

Value

An object of class `mdl_df` in long-format.

Examples

```
library(tsibble)
library(fable)
AirPassengers %>%
  as_tsibble() %>%
  model("ESN" = ESN(value)) %>%
  filter_esn()
```

fitted.ESN	<i>Extract fitted values from a trained ESN</i>
------------	---

Description

Extract fitted values from a trained ESN as tsibble.

Usage

```
## S3 method for class 'ESN'
fitted(object, ...)
```

Arguments

object	An object of class <code>mdl_df</code> , containing an ESN model.
...	Currently not in use.

Value

Fitted values extracted from the object.

Examples

```
library(tsibble)
library(fable)
AirPassengers %>%
  as_tsibble() %>%
  model("ESN" = ESN(value)) %>%
  fitted()
```

forecast.ESN	<i>Forecast an Echo State Network</i>
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Description

Forecast an Echo State Network (ESN) from a trained model via recursive forecasting. Forecast intervals are generated by simulating future sample path based on a moving block bootstrap of the residuals and estimating the quantiles from the simulations. The function is a wrapper for `forecast_esn()` and intended to be used in combination with `fabletools::model()`.

Usage

```
## S3 method for class 'ESN'
forecast(
  object,
  new_data,
  normal = TRUE,
  n_sim = 200,
  specials = NULL,
  xreg = NULL,
  ...
)
```

Arguments

object	An object of class <code>mdl_df</code> , containing an ESN model.
new_data	Forecast horizon (n-step ahead forecast).
normal	Logical value. If <code>TRUE</code> , <code>dist_normal()</code> is used, otherwise <code>dist_sample()</code> .
n_sim	Integer value. The number of future sample path generated during simulation.
specials	Currently not in use.
xreg	A <code>tsibble</code> containing exogenous variables.
...	Currently not in use.

Value

An object of class `fbl_ts` ("fable").

Examples

```
library(tsibble)
library(fable)
AirPassengers %>%
  as_tsibble() %>%
  model("ESN" = ESN(value)) %>%
  forecast(h = 18)
```

forecast_esn

Forecast an Echo State Network

Description

Forecast an Echo State Network (ESN) from a trained model via recursive forecasting. Forecast intervals are generated by simulating future sample path based on a moving block bootstrap of the residuals and estimating the quantiles from the simulations.

Usage

```
forecast_esn(  
  object,  
  n_ahead = 18,  
  levels = c(80, 95),  
  n_sim = 100,  
  n_seed = 42  
)
```

Arguments

<code>object</code>	An object of class <code>esn</code> . The result of a call to <code>train_esn()</code> .
<code>n_ahead</code>	Integer value. The number of periods for forecasting (i.e. forecast horizon).
<code>levels</code>	Integer vector. The levels of the forecast intervals, e.g., 80% and 95%.
<code>n_sim</code>	Integer value. The number of future sample path generated during simulation.
<code>n_seed</code>	Integer value. The seed for the random number generator (for reproducibility).

Value

A list containing:

- `point`: Numeric vector containing the point forecasts.
- `interval`: Numeric matrix containing the forecast intervals.
- `sim`: Numeric matrix containing the simulated future sample path.
- `levels`: Integer vector. The levels of the forecast intervals.
- `actual`: Numeric vector containing the actual values.
- `fitted`: Numeric vector containing the fitted values.
- `n_ahead`: Integer value. The number of periods for forecasting (forecast horizon).
- `model_spec`: Character value. The model specification as string.

Examples

```
xdata <- as.numeric(AirPassengers)  
xmodel <- train_esn(y = xdata)  
xfcst <- forecast_esn(xmodel, n_ahead = 12)  
plot(xfcst)
```

Description

Return summary statistics from trained ESN models during random search as tibble.

- model: Model identifier.
- loglik: Log-likelihood.
- nobs: Number of observations.
- df: Effective degrees of freedom.
- lambda: Regularization parameter.
- aic: Akaike Information Criterion.
- aicc: Corrected Akaike Information Criterion.
- bic: Bayesian Information Criterion.
- hqc: Hannan-Quinn Information Criterion.
- mse: Mean Squared Error.
- mae: Mean Absolute Error.

Usage

```
## S3 method for class 'ESN'  
glance(x, ...)
```

Arguments

x	An object of class mdl_df, containing an ESN model.
...	Currently not in use.

Value

Summary statistics extracted from the object.

Examples

```
library(tsibble)  
library(fable)  
AirPassengers %>%  
as_tsibble() %>%  
model("ESN" = ESN(value)) %>%  
glance()
```

is.esn	<i>Checks if object is of class "esn"</i>
--------	---

Description

Returns TRUE if the object is of class "esn".

Usage

```
is.esn(object)
```

Arguments

object object to be tested.

Value

Logical value. If TRUE, the object is of class "esn".

Examples

```
xdata <- as.numeric(AirPassengers)
xmodel <- train_esn(y = xdata)
is.esn(xmodel)
```

is.forecast_esn	<i>Checks if object is of class "forecast_esn"</i>
-----------------	--

Description

Returns TRUE if the object is of class "forecast_esn".

Usage

```
is.forecast_esn(object)
```

Arguments

object object to be tested.

Value

Logical value. If TRUE, the object is of class "forecast_esn".

Examples

```
xdata <- as.numeric(AirPassengers)
xmodel <- train_esn(y = xdata)
xfcst <- forecast_esn(xmodel, n_ahead = 12)
is.forecast_esn(xfcst)
```

m4_data

M4 dataset

Description

tsibble with six monthly time series from the M4 Forecasting Competition. The datasets contains the following time series:

- M21655 (Demographic), 1995 Jan - 2015 Mar
- M21683 (Demographic), 2000 Jan - 2023 Apr
- M2717 (Macro), 1996 Jan - 2016 Nov
- M28597 (Industry), 1996 Jan - 2016 Dec
- M42529 (Finance), 2001 Jan - 2009 Apr
- M4813 (Macro), 1994 Apr - 2006 May

Usage

```
data(m4_data)
```

Format

A time series object of class tsibble with 1.152 rows and 4 columns:

- series: Unique identifier as character (key variable).
- category: Category (e.g., Demographic, Macro) as factor.
- index: Date as yearmonth (index variable).
- value: Value as numeric (measurement variable).

Source

[M4 Forecasting Competition](#)

Examples

```
data(m4_data)
```

 model_sum.ESN

Model specification of a trained ESN model

Description

Provides a compact overview of the model specification in the format `ESN({n_states, alpha, rho}, {n_models, df})`.

Usage

```
## S3 method for class 'ESN'
model_sum(x)
```

Arguments

`x` An object of class `mdl_df`, containing an ESN model.

Value

Model summary extracted from the object.

Examples

```
library(tsibble)
library(fable)
AirPassengers %>%
  as_tsibble() %>%
  model("ESN" = ESN(value))
```

 plot.esn

Plot internal states of a trained ESN model

Description

Plot internal states (i.e., the reservoir) of a trained ESN model as line chart.

Usage

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

Arguments

`x` An object of class `esn`. The result of a call to `train_esn()`.
`...` Further arguments passed to `matplot()`.

Value

Line chart of internal states.

Examples

```
xdata <- as.numeric(AirPassengers)
xmodel <- train_esn(y = xdata)
plot(xmodel)
```

plot.forecast_esn *Plot forecasts of a trained ESN model*

Description

Plot point forecasts and forecast intervals, actual values of a trained ESN model. Optionally, test data (out-of-sample) and fitted values can be added to the plot.

Usage

```
## S3 method for class 'forecast_esn'
plot(x, test = NULL, fitted = TRUE, interval = TRUE, n_obs = NULL, ...)
```

Arguments

x	An object of class forecast_esn. The result of a call to forecast_esn().
test	Numeric vector. Test data, i.e., out-of-sample actual values.
fitted	Logical value. If TRUE, fitted values are added.
interval	Logical value. If TRUE, forecast intervals are added.
n_obs	Integer value. If NULL, all in-sample values are shown, otherwise only the last n_obs.
...	Currently not in use.

Value

Line chart of point forecast and actual values.

Examples

```
xdata <- as.numeric(AirPassengers)
xmodel <- train_esn(y = xdata)
xfcst <- forecast_esn(xmodel, n_ahead = 12)
plot(xfcst)
```

print.esn	<i>Print model specification of the trained ESN model</i>
-----------	---

Description

Provides a compact overview of the model specification in the format ESN({n_states, alpha, rho}, {n_models, df}).

Usage

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

Arguments

x	An object of class esn. The result of a call to train_esn().
...	Currently not in use.

Value

Print specification of the trained ESN model.

Examples

```
xdata <- as.numeric(AirPassengers)
xmodel <- train_esn(y = xdata)
print(xmodel)
```

report.ESN	<i>Provide a detailed summary of the trained ESN model</i>
------------	--

Description

Provide a detailed summary of the trained ESN model. The function is a wrapper for summary.esn().

Usage

```
## S3 method for class 'ESN'
report(object, ...)
```

Arguments

object	An object of class mdl_df, containing an ESN model.
...	Currently not in use.

Value

Print detailed model summary.

Examples

```
library(tsibble)
library(fable)
AirPassengers %>%
  as_tsibble() %>%
  model("ESN" = ESN(value)) %>%
  report()
```

reservoir

Return the reservoir from a trained ESN as tibble

Description

Return the reservoir (internal states) from a trained ESN as tibble. The function works only for models of class ESN.

Usage

```
reservoir(object)
```

Arguments

object An object of class `mdl_df`, containing an ESN model.

Value

A tibble containing the reservoir (internal states).

Examples

```
library(tsibble)
library(fable)
AirPassengers %>%
  as_tsibble() %>%
  model("ESN" = ESN(value)) %>%
  reservoir()
```

residuals.ESN	<i>Extract residuals from a trained ESN</i>
---------------	---

Description

Extract residuals from a trained ESN as tsibble.

Usage

```
## S3 method for class 'ESN'
residuals(object, ...)
```

Arguments

object	An object of class <code>mdl_df</code> , containing an ESN model.
...	Currently not in use.

Value

Residuals extracted from the object.

Examples

```
library(tsibble)
library(fable)
AirPassengers %>%
  as_tsibble() %>%
  model("ESN" = ESN(value)) %>%
  residuals()
```

run_reservoir	<i>Run reservoir</i>
---------------	----------------------

Description

Run reservoir creates the internal states for the ESN.

Arguments

input	Numeric matrix containing the input features
win	Numeric matrix. The input weight matrix.
wres	Numeric matrix. The reservoir weight matrix.
alpha	Numeric value. The leakage rate (smoothing parameter).

Value

states train Numeric matrix with the internal states.

summary.esn	<i>Provide a detailed summary of the trained ESN model</i>
-------------	--

Description

Provide a detailed summary of the trained ESN model.

Usage

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

Arguments

object	An object of class esn. The result of a call to train_esn().
...	Currently not in use.

Value

Print detailed model summary.

Examples

```
xdata <- as.numeric(AirPassengers)  
xmodel <- train_esn(y = xdata)  
summary(xmodel)
```

synthetic_data	<i>Synthetic data</i>
----------------	-----------------------

Description

tibble with ten synthetic time series. The dataset contains the following time series:

- Square Wave
- Sawtooth Wave
- Harmonic Wave
- Harmonic Wave w/ Trend
- Amplitude Modulated Wave
- Frequency Modulated Wave
- AR(1) Process
- MA(2) Process
- White Noise Process
- Random Walk Process

Usage

```
data(synthetic_data)
```

Format

An object of class `tibble` with 2,000 rows and 3 columns:

- `variable`: Unique identifier as character (key variable).
- `index`: Index as integer (index variable).
- `value`: Value as numeric (measurement variable).

Examples

```
data(synthetic_data)
```

tidy.ESN	<i>Estimated coefficients</i>
----------	-------------------------------

Description

Return the estimated coefficients from a trained ESN as `tibble`.

Usage

```
## S3 method for class 'ESN'
tidy(x, ...)
```

Arguments

`x` An object of class `mdl_df`, containing an ESN model.
`...` Currently not in use.

Value

Coefficients extracted from the object.

Examples

```
library(tsibble)
library(fable)
AirPassengers %>%
  as_tsibble() %>%
  model("ESN" = ESN(value)) %>%
  tidy()
```


train_esn

*Train an Echo State Network***Description**

Train an Echo State Network (ESN) to a univariate time series. The function automatically manages data pre-processing, reservoir generation (i.e., internal states) and model estimation and selection.

Usage

```
train_esn(
  y,
  lags = 1,
  inf_crit = "bic",
  n_diff = NULL,
  n_states = NULL,
  n_models = NULL,
  n_initial = NULL,
  n_seed = 42,
  alpha = 1,
  rho = 1,
  density = 0.5,
  lambda = c(1e-04, 2),
  scale_win = 0.5,
  scale_wres = 0.5,
  scale_inputs = c(-0.5, 0.5)
)
```

Arguments

y	Numeric vector containing the response variable.
lags	Integer vector with the lag(s) associated with the input variable.
inf_crit	Character value. The information criterion used for variable selection <code>inf_crit = c("aic", "aicc", "bic", "hqc")</code> .
n_diff	Integer vector. The nth-differences of the response variable.
n_states	Integer value. The number of internal states per reservoir.
n_models	Integer value. The maximum number of (random) models to train for model selection.
n_initial	Integer value. The number of observations of internal states for initial drop out (throw-off).
n_seed	Integer value. The seed for the random number generator (for reproducibility).
alpha	Numeric value. The leakage rate (smoothing parameter) applied to the reservoir.
rho	Numeric value. The spectral radius for scaling the reservoir weight matrix.
density	Numeric value. The connectivity of the reservoir weight matrix (dense or sparse).

<code>lambda</code>	Numeric vector. Lower and upper bound of lambda sequence for ridge regression.
<code>scale_win</code>	Numeric value. The lower and upper bound of the uniform distribution for scaling the input weight matrix.
<code>scale_wres</code>	Numeric value. The lower and upper bound of the uniform distribution for scaling the reservoir weight matrix.
<code>scale_inputs</code>	Numeric vector. The lower and upper bound for scaling the time series data.

Value

A list containing:

- `actual`: Numeric vector containing the actual values.
- `fitted`: Numeric vector containing the fitted values.
- `resid`: Numeric vector containing the residuals.
- `states_train`: Numeric matrix containing the internal states.
- `method`: A list containing several objects and meta information of the trained ESN (weight matrices, hyperparameters, model metrics, etc.).

Examples

```
xdata <- as.numeric(AirPassengers)
xmodel <- train_esn(y = xdata)
summary(xmodel)
```

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