

# Package ‘marima’

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**Type** Package

**Title** Multivariate ARIMA and ARIMA-X Analysis

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**Description** Multivariate ARIMA and ARIMA-X estimation using Spliid's algorithm (marima()) and simulation (marima.sim()).

**License** GPL-2

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arma.filter	<i>arma.filter</i>
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## Description

Filtering of (kvar-variate) time series with marima type model.

Calculation of residuals and filtered values of timeseries using a marima model.

## Usage

```
arma.filter(series = NULL, ar.poly = array(diag(kvar), dim = c(kvar, kvar,
1)), ma.poly = array(diag(kvar), dim = c(kvar, kvar, 1)), means = 1)
```

## Arguments

series	matrix holding the kvar by n multivariate timeseries (if (kvar > n) the series is transposed and a warning is given).
ar.poly	(kvar, kvar, p+1) array containing autoregressive matrix polynomial model part. If the filtering is to be performed for undifferenced data when the analysis (in marima) was done for differenced data, the input array ar.poly should incorporate the ar-representation of the differencing operation (using, for example: ar.poly <- pol.mul(ar.estimate, dif.poly, L = ( dim(ar.estimate)[3]+dim(dif.poly)[3])), where 'dif.poly' was obtained when differencing the time series (using define.dif) before analysing it with marima (giving the ar.estimate) .
ma.poly	(kvar, kvar, q+1) array containing moving average matrix polynomial model part. If a leading unity matrix is not included in the ar- and/or the ma-part of the model this is automatically taken care of in the function (in that case the dimensions of the model arrays used in arma.filter() are, respectively, (kvar, kvar, p+1) and (kvar, kvar, q+1)).
means	vector (length = kvar) indicating whether means are subtracted or not (0/1). Default : means = 1 saying that all means are subtracted (equivalent to means = c(1, 1, ..., 1)).

**Value**

estimates = estimated values for input series

residuals = corresponding residuals. It is noted that the residuals computed by arma.filter may deviate slightly from the marima-residuals (which are taken from the last repeated regression step performed). The residuals computed by arma.filter are constructed by filtering (successive use of the arma model) and using a heuristic method for the first residuals.

averages = averages of variables in input series

mean.pattern = pattern of means as used in filtering

**Examples**

```
library(marima)
data(austr)
series<-t(austr)[,1:90]
# Define marima model
Model5 <- define.model(kvar=7,ar=1,ma=1,rem.var=1,reg.var=6:7)

# Estimate marima model
Marima5 <- marima(series,Model5$ar.pattern,Model5$ma.pattern,penalty=1)

# Calculate residuals by filtering
Resid <- arma.filter(series, Marima5$ar.estimates,
  Marima5$ma.estimates)

# Compare residuals

plot(Marima5$residuals[2, 5:90], Resid$residuals[2, 5:90],
  xlab='marima residuals', ylab='arma.filter residuals')
```

---

 arma.forecast

*arma.forecast*


---

**Description**

Forecasting of (multivariate) time series of using marima type model.

**Usage**

```
arma.forecast(series = NULL, marima = NULL, nstart = NULL, nstep = 1,
  dif.poly = NULL, check = TRUE)
```

**Arguments**

series	<p>matrix holding the kvar-variate timeseries. The series is assumed to have the same format as the timeseries analysed by marima BEFORE differencing (if differencing was used via define.dif) (the length, though, does not need to be the same but can be shorter or longer). Results from estimating the model (for the differenced data, if used) are assumed to be saved in the input-object 'marima' (see 'usage') by marima.</p> <p>The series is assumed to have the total length=(nstart+nstep) (but it may be longer. In any case the forecasting is starting from nstart continuing to nstart+nstep. Future values already present or initialised, for example, as NAs are overwritten with the forecasted values.)</p> <p>An example of a series prepared for forecasting is in the marima library: 'data(austr)': (see below, the example).</p> <p>If future (independent) x-values for the forecasting are to be used these values must be supplied in 'series' at the proper places before calling 'arma.forecast(...)' (that is except the x-value(s) corresponding to the last prediction).</p>
marima	<p>the object holding the marima results to be used for the forecasting, that is an output object created by marima.</p> <p>If the ar- and/or the ma-model do not include a leading unity matrix this is automatically taken care of in the function (in that case the dimensions of the model arrays used will be, respectively, (kvar, kvar, p+1) and (kvar, kvar, q+1)) after inserting the leading unity matrix (if the object 'marima' was produced by marima, this will automatically be OK).</p>
nstart	starting point for forecasting (1st forecast values will be for time point t = nstart+1).
nstep	length of forecast (forecasts will be for time points nstart+1,...,nstart+nstep).
dif.poly	(most often) output from the function define.dif holding the ar-representation of the differencing polynomial (define.dif\$dif.poly). If a differenced timeseries was analysed by marima the forecast-variance/covariance matrices are calculated for the aggregated (original) timeseries if 'dif.poly' is specified. If not, the forecast-variance/covariance matrices are calculated for the differenced time series. If forecasting is wanted for the original (not differenced) time series the 'dif.poly' created by define.dif must be specified.
check	If check=TRUE (default) various checks and printouts are carried out.

**Value**

forecasts = forecasted values following the nstart first values of the input series (at time points 'nstart+1,...,nstart+nstep'). The forecasted values will be (over-) written in the input series at the proper future positions (if relevant).

residuals = corresponding residuals for input series followed by nstep future residuals (all=0).

prediction.variances = (kvar, kvar, nstep) array containing prediction covariance matrices corresponding to the nstep forecasts.

nstart = starting point for prediction (1st prediction at point nstart+1).

nstep = length of forecast

**Examples**

```

library(marima)
data(austr)
series<-austr
Model5 <- define.model(kvar=7, ar=1, ma=1, rem.var=1, reg.var=6:7)
Marima5 <- marima(ts(series[1:90, ]), Model5$ar.pattern, Model5$ma.pattern,
penalty=1)

nstart <- 90
nstep <- 10
cat("Calling arma.forecast.\n")
cat("In the example the input series is dim(length,kvar).\n")
cat("and of type ts() (timeseries) for illustration. \n")
Forecasts <- arma.forecast(series=ts(series), marima=Marima5,
nstart=nstart, nstep=nstep )
Year<-series[91:100,1]
One.step <- Forecasts$forecasts[, (nstart+1)]
One.step
Predict <- Forecasts$forecasts[ 2, 91:100]
Predict
stdv<-sqrt(Forecasts$pred.var[2, 2, ])
upper.lim=Predict+stdv*1.645
lower.lim=Predict-stdv*1.645
Out<-rbind(Year, Predict, upper.lim, lower.lim)
print(Out)
# plot results:
plot(series[1:100, 1], Forecasts$forecasts[2, ], type='l', xlab='Year',
ylab='Rate of armed suicides', main='Prediction of suicides by firearms',
ylim=c(0.0, 4.1))
lines(series[1:90, 1], series[1:90, 2], type='p')
grid(lty=2, lwd=1, col='black')
Years<-2005:2014
lines(Years, Predict, type='l')
lines(Years, upper.lim, type='l')
lines(Years, lower.lim, type='l')
lines(c(2004.5, 2004.5), c(0.0, 2.0), lty = 2)

```

---

austr

*Data set for testing marima package (australian killings)*


---

**Description**

Data for marima examples.

**Usage**

```
data(austr)
```

**Format**

A data frame (austr) with 7 columns and 100 rows.

**Year** Year for data

**suic.fire** Rate of suicides by firearms

**homi.fire** Rate of homicides by firearms

**suic.other** Rate of suicides by non firearms

**homi.other** Rate of homicides by non firearms

**leg** Legislation against firearms in effect

**acc.elg** Accumulated effect of legislation in years

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C20

*Data set for testing marima package (Copenhagen Stocks)*

---

**Description**

Two years of prices for 18 shares from the Copenhagen Stock Exchange C20 index, covering the most valuable companies. Two shares have been removed (Maersk A = almost identical to Maersk B) and ISS which is incomplete for the period considered.

**Usage**

`data(C20)`

**Format**

A data frame (C20) with 1+18+18 columns and 517 rows (about two full years).

**Dates** Format for date is 2016-04-01

**CARL.fin** Closing price for stock 'Carlsberg' .

**CHR..fin** Closing price for stock 'Christian Hansen' .

**COLO.fin** Closing price for stock 'Coloplast' .

**DANS.fin** Closing price for stock 'Danske Bank' .

**DSV..fin** Closing price for stock 'DSV' .

**GEN..fin** Closing price for stock 'Genmap' .

**GN.2.fin** Closing price for stock 'GN St. Nord' .

**FLS..fin** Closing price for stock 'FL Smidth' .

**JYSK.fin** Closing price for stock 'Jyske Bank' .

**MAER.fin** Closing price for stock 'Maersk B' .

**NDA..fin** Closing price for stock 'Nordea Bank' .

**NOVO.fin** Closing price for stock 'Novo' .

**NZYM.fin** Closing price for stock 'Novozymes' .  
**PNDO.fin** Closing price for stock 'Pandora' .  
**TDC..fin** Closing price for stock 'TDC' .  
**TRYG.fin** Closing price for stock Pandora' .  
**VWS..fin** Closing price for stock 'Vestas Wind' .  
**WDH..fin** Closing price for stock 'Wiliam Demant' .  
**CARL.ave** Average price for stock 'Carlsberg' .  
**CHR.ave** Average price for stock 'Christian Hansen' .  
**COLO.ave** Average price for stock 'Coloplast' .  
**DANS.ave** Average price for stock 'Danske Bank' .  
**DSV.ave** Average price for stock 'DSV' .  
**GEN.ave** Average price for stock 'Genmap' .  
**GN.2.ave** Average price for stock 'GN St. Nord' .  
**FLS.ave** Average price for stock 'FL Smidth' .  
**JYSK.ave** Average price for stock 'Jyske Bank' .  
**MAER.ave** Average price for stock 'Maersk B' .  
**NDA.ave** Average price for stock 'Nordea Bank' .  
**NOVO.ave** Average price for stock 'Novo' .  
**NZYM.ave** Average price for stock 'Novozymes' .  
**PNDO.ave** Average price for stock Pandora' .  
**TDC..ave** Average price for stock 'TDC' .  
**TRYG.ave** Average price for stock 'Pandora' .  
**VWS..ave** Average price for stock 'Vestas Wind' .  
**WDH..ave** Average price for stock 'William Demant' .

## Examples

```

# Example 1:

library(marima)
data(C20)

selects <- c(2,7,11)

cat("Multivariate model for ",colnames(C20)[selects]," \n")

Data <- data.frame(C20[,selects])
colnames(Data) <- colnames(C20)[selects]

log.Data <- log(Data)
kvar <- length(selects)
k <- c(1:kvar)
  
```

```

difs <- rep(1,length(selects))

difference <- rbind(k , difs)

dlog.Data <- 100*t(define.dif(log.Data,difference)$y.dif)

cat("dlog.Data represents the percentage change from day
to day. \n")

mod <- define.model(kvar = kvar, ar=c(1:2),ma=c(1))

Model <- marima(dlog.Data,
  ar.pattern=mod$ar.pattern, ma.pattern=mod$ma.pattern,penalty=2)

short.form(Model$ar.estimates,leading=FALSE)
short.form(Model$ma.estimates,leading=FALSE)

# Example 2:
library(marima)
data(C20)

selects <- c(13)

cat("Univariate model for ",colnames(C20)[selects]," \n")

Data <- data.frame(C20[,selects])
colnames(Data) <- colnames(C20)[selects]

log.Data <- log(Data)
kvar <- length(selects)
k <- c(1:kvar)
difs <- rep(1,length(selects))

difference <- rbind(k , difs)

dlog.Data <- 100*t(define.dif(log.Data,difference)$y.dif)

mod <- define.model(kvar = kvar, ar=c(1:2),ma=c(1))

Model <- marima(dlog.Data,
  ar.pattern=mod$ar.pattern, ma.pattern=mod$ma.pattern,penalty=2)

short.form(Model$ar.estimates,leading=FALSE)
short.form(Model$ma.estimates,leading=FALSE)

```

---

check.one

*check.one*


---

### Description

Function to check and insert leading unity matrix if NOT present.



**Usage**

```
check.one(polyn = NULL)
```

**Arguments**

polyn (k, k, ...) matrix polynomial with or without leading unity matrix.

**Value**

polyn (array) with a leading unity matrix being inserted if not present.

**Examples**

```
set.seed(4711)
X <- array(rnorm(32),dim=c(4, 4, 2))
X <- check.one(X)
short.form(X)
```

---

define.dif

*define.dif*


---

**Description**

Function to generate and apply a differencing matrix polynomial (autoregressive form) defined by a pattern.

To be used before calling marima in order to difference the timeseries before the marima analysis. The averages of the variables in the time series are subtracted from the input series before differencing.

**Usage**

```
define.dif(series = series, difference = NULL)
```

**Arguments**

series = kvar-variate timeseries (kvar by n matrix).  
difference = 2 by L matrix defining L differencing operations.

**Value**

y.dif = the differenced timeseries (the complete part)

y.lost = the first observations lost because of differencing

dif.poly = differencing polynomial array = c(kvar, kvar, ...) holding the autoregressive representation of the specified differencing

averages = the averages of the original series as they were subtracted before differencing

dif.series = the differenced series (y.lost followed by y.dif)

## Examples

```

# Generate Y=series with 4 variables for illustration:
set.seed(4711)
Y<-matrix(round(100*rnorm(40)+10), nrow=4)

# Example 1: use of difference parameter: If
difference=c(2, 1, 2, 1, 3, 12)
difference
# the variable 2 is differenced
# twice, and variable 3 is differenced once with lag=12.

# Example 2:
poly <- define.dif(series=Y, difference=c(2, 1, 3, 1, 3, 1))
poly
# Generates a (4-variate) polynomial differencing array (with a leading
# unity matrix corresponding to lag=0, and (in the example) differencing
# of variable 2 for lag 1 and variable 3 for lag 1 but twice. Afterwards
# the series Y is differenced accordingly. Results in poly$series and
# poly$dif.poly .

# Example 3: Generation and application of multivariate differencing
# polynomial. Re-use the 4-variate time series and use the
# differencing polynomial (ar-form):
# var=1, dif=1, var=2, dif=6, and var=3 and 4, no differencing.
dif.y <-define.dif(Y, c(1, 1, 2, 6, 3, 0, 4, 0))
# Now dif.y contains the differenced series and the differencing
# polynomial. Print the generated polynomial in short form:
short.form(dif.y$dif.poly)
# Specifying no differencing (3, 0 and 4, 0) may be omitted:
dif.y <-define.dif(Y, c(1, 1, 2, 6))
dif.y

# Example 4:
y<-matrix(round(rnorm(1200)*100+50), nrow=6)
library(marima)
difference<-c(3, 2, 4, 0, 5, 0, 6, 7)
matrix(difference, nrow=2)
Y<-define.dif(y, difference=difference)
round(rowMeans(Y$dif.series), 2)
round(Y$averages, 2)

```

---

define.model

*define.model*


---

## Description

Function to define multivariate arma model (indicator form) for marima.

**Usage**

```
define.model(kvar = 1, ar = 0, ma = 0, rem.var = 0, reg.var = 0,
  no.dep = NULL, print = 0, ar.fill = NULL, ar.rem = NULL,
  ma.fill = NULL, ma.rem = NULL, indep = NULL)
```

**Arguments**

kvar	dimension of time series
ar	autoregression definition. For example ar=c(1, 2, 12) will generate autoregression at lags 1, 2 and 12.
ma	moving average definition. Works like ar. If ma=c(1, 2) moving average terms at lags 1 and 2 are defined.
rem.var	no. of variable(s) not to be considered in marima.
reg.var	no. of variable(s) that can only act as regression variable(s) such as (typically) a so-called leading indicator.
no.dep	sequence of pairs of variables. For example no.dep=c(1, 2, 2, 3) means that variable 2 is not allowed in model for variable 1, and variable 3 is not allowed in model for variable 2.
print	(!0/0) If !0 is used, the generated patterns of the arma model and other informations are printed on the console. If 0 is used, no printout of the arma patterns are given.
ar.fill	sequence of triplets: c(dependent variable, independent variable, lag). ar.fill=c(2, 3, 12): Insert ar-indicator for model for dependent variable 2 and independent variable 3 at lag 12.
ar.rem	sequence of triplets c(dependent variable, independent variable, lag). ar.rem=c(2, 3, 12): remove (if present) ar-indicator for model for dependent variable 2 and independent variable 3 at lag 12.
ma.fill	sequence of triplets: c(dependent variable, independent variable, lag). ma.fill=c(2, 3, 12): Insert ma-indicator for model for dependent variable 2 and independent variable 3 at lag 12.
ma.rem	sequence of triplets c(dependent variable, independent variable, lag). ma.rem=c(2, 3, 12): remove (if present) ma-indicator for model for dependent variable 2 and independent variable 3 at lag 12.
	The various parameters may (in some cases) accomplish the same model requirements. The routine define.model apply these input parameters successively in the following order: 1) rem.var, 2) reg.var, 3) indep, 4) no.dep, 5) ar.fill, 6) ar.rem, 7) ma.fil, 8) ma.rem
	The parameters ar.fill, ar.rem, ma.fill and ma.rem are applied last, and in that order. They overwrite what previously has been defined.
indep	no. of variable(s) that are independent of the other variables. indepc(2, 4) makes variables 2 and 4 independent of all other variables. Variables 2 and 4 may influence other variables.

**Value**

ar.pattern a matrix polynomial (an array) with 1's and 0's defining the autoregressive matrix polynomial to be fitted by marima (an array with  $\text{dim}=\text{c}(\text{kvar}, \text{kvar}, 1+\text{ar\_order})$  (with leading unity matrix)).

ma.pattern a matrix polynomial (an array) with 1's and 0's defining the moving average matrix polynomial to be fitted by marima (an array with  $\text{dim}=\text{c}(\text{kvar}, \text{kvar}, 1+\text{ma\_order})$  (including the leading unity matrix)).

**Examples**

```
#
# Example 1: 3-variate arma model with ar-lags at 1 and 2, and an
# ma-term at lag 1. And var=3 is a regression variable (X-variable).
#
Model1 <- define.model(kvar=3, ar=c(1, 2), ma=c(1), reg.var=3)
short.form(Model1$ar.pattern)
short.form(Model1$ma.pattern, leading=FALSE)
#
# The object Model1 contains the ar- and ma-pattern arrays as defined.
#
# Model1$ar.pattern and Model1$ma.pattern are used as input to
# marima in order to define the model to be estimated.
#
# Example 2: arma model with ar-lags at 1, 2 and 6, and var=3
# regression variable (X-variable).
#
Model2 <- define.model(kvar=3, ar=c(1, 2, 6), ma=c(1), reg.var=3)
# Print the ar- and ma-polynomial patterns using
short.form(Model2$ar.pattern, leading=FALSE)
short.form(Model2$ma.pattern, leading=TRUE)
#
# Example 3: arma model with ar-lags at 1, 2 and 6, and reg.var=3
# (X-variable). ma-order=1. Finally (ar.fill=c(2, 3, 4) puts a '1'
# for (dep-var=2, indep-var=3, ar-lag=4).
#
# If further modifications of the ar- or ma-patterns are needed, it
# can be accomplished before calling marima (Model3$ar.pattern and
# Model3$ma.pattern are arrays).
#
Model3 <- define.model(kvar=3, ar=c(1, 2, 6), ma=c(1), reg.var=3,
  ar.fill=c(2, 3, 4))
short.form(Model3$ar.pattern)
short.form(Model3$ma.pattern)
#
Model4 <- define.model(kvar=3, ar=c(1, 2, 6), ma=c(1), reg.var=3,
  ar.fill=c(2, 3, 4), indep=c(1))
short.form(Model4$ar.pattern)
short.form(Model4$ma.pattern, leading=FALSE)
```

---

define.sum	<i>define.sum</i>
------------	-------------------

---

**Description**

Function to aggregate multivariate time series. Reverse of function 'define.dif'.

**Usage**

```
define.sum(series = NULL, difference = NULL, averages = 0)
```

**Arguments**

series	series to be summed up.
difference	differencing pattern (see define.dif).
averages	of the individual series that (usually) have been subtracted when differencing the time series (if so, the averages are supplied in the output from define.dif(...)).

**Value**

sum.series the summed series.

**Examples**

```
set.seed(4711)
y <- round(matrix(100*rnorm(48), nrow=4))
difference=matrix(c(1, 1, 1, 1, 2, 1, 3, 6), nrow=2)
dy <- define.dif(y, difference)$dif.series
averages <- define.dif(y, difference)$averages
sum.y <- define.sum(dy, difference, averages)$series.sum
y
dy
averages
sum.y
```

---

forec.var	<i>forec.var</i>
-----------	------------------

---

**Description**

Function for calculation of variances of nstep forecasts using a marima type model.

**Usage**

```
forec.var(marima, nstep = 1, dif.poly = NULL)
```

**Arguments**

marima	marima object (cov.u and ar.estimate and ma.estimate are used)
nstep	length of forecast
dif.poly	autoregressive representation of differencing polynomial as constructed by the function define.dif(...) when the time series is differenced (if so) before being analysed by marima.

**Value**

pred.var = variance-covariances for nstep forecasts (an array with dimension (kvar, kvar, nstep)).  
 rand.shock = corresponding random shock representation of the model used.

---

inverse.form	<i>inverse.form</i>
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---

**Description**

Calculation of inverse form for arma model

**Usage**

```
inverse.form(ar.poly, ma.poly, L)
```

**Arguments**

ar.poly	=autoregressive matrix part of model (array(k, k, ar-order)).
ma.poly	=moving average matrix part of model (array(k, k, ma-order)).
L	=order of return polynomial (length=L+1 including leading unity matrix).

**Value**

inverse form for arma model up to order L (array(k, k, L+1)).

**Examples**

```
set.seed(4711)
p1 <- check.one(matrix(rnorm(16), nrow=4))
p2 <- check.one(array(rnorm(32), dim=c(4, 4, 2)))
inverse <- inverse.form(ar.poly=p1, ma.poly=p2, L=6)
short.form(inverse)
```

---

lead.one	<i>lead.one</i>
----------	-----------------

---

**Description**

Function to add (or remove) a leading unity matrix to (from) an array (being an array representation of ar- or ma-polynomial).

**Usage**

```
lead.one(polyn = NULL, add = 0)
```

**Arguments**

polyn	an input polynomial (an array).
add	indicator for adding or removing unity matrix: +1 = add leading unity matrix, -1 = remove leading matrix.

**Value**

changed array (with leading unity matrix inserted or removed).

---

marima	<i>marima</i>
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---

**Description**

Estimate multivariate arima and arima-x models. Setting up the proper model for (especially) arima-x estimation can be accomplished using the routine 'define.model' that can assist in setting up the necessary autoregressive and moving average patterns used as input to 'marima'.

A more elaborate description of 'marima' and how it is used can be downloaded from:

<http://www.imm.dtu.dk/~hspl/marima.use.pdf>

**Usage**

```
marima(DATA = NULL, ar.pattern = NULL, ma.pattern = NULL, means = 1,
       max.iter = 50, penalty = 0, weight = 0.33, Plot = "none",
       Check = FALSE)
```

**Arguments**

DATA	time series matrix, $\text{dim}(\text{DATA}) = c(\text{kvar}, n)$ , where 'kvar' is the dimension of the time series and 'n' is the length of the series. If DATA is organized (n, kvar) (as a data.frame e.g.) it is automatically transposed in marima, and the user need not care about it. Also, and consequently, the output residuals and fitted values matrices are both organised $c(\text{kvar}, n)$ at return from marima. The DATA is checked for completeness. Cases which include 'NA's or 'NaN's are initially left out. A message is given (on the console) and the active cases are given in the output object (...\$used.cases). If DATA is a time series object it is transformed to a matrix and a warning is given ( <code>if(is.ts(DATA)) DATA &lt;- as.matrix(data.frame(DATA))</code> ) and a message is given (on the console).
ar.pattern	autoregressive pattern for model (see define.model). If ar.pattern is not specified a pure ma-model is estimated.
ma.pattern	moving average pattern for model (see define.model). If ma.pattern is not specified a pure ar-model is estimated. In this case the estimation is carried out by regression analysis in a few steps.
means	0/1 indicator vector of length kvar, indicating which variables in the analysis should be means adjusted or not. Default: means=1 and all variables are means adjusted. If means=0 is used, no variables are means adjusted.
max.iter	max. number of iterations in estimation (max.iter=50 is default which, generally, is more than enough).
penalty	parameter used in the R function 'step' for stepwise model reduction. If penalty=2, the conventional AIC criterion is used. If penalty=0, no stepwise reduction of model is performed. Generally $0 \leq \text{penalty} \leq 2$ works well (especially penalty=1). The level of significance of the individual parameter estimates in the final model can be checked by considering the (approximate) 'ar.pvalues' and the 'ma.pvalues' calculated by marima.
weight	weighting factor for smoothing the repeated estimation procedure. Default is weight=0.33 which often works well. If weight>0.33 (e.g. weight=0.66) is specified more damping will result. If a large damping factor is used, the successive estimations are more cautious, and a slower (but safer) convergence (if possible) may result (max.iter may have to be increased to, say, max.iter=75).
Plot	'none' or 'trace' or 'log.det' indicates a plot that shows how the residual covariance matrix (resid.cov) develops with the iterations. If Plot= 'none' no plot is generated. If Plot= 'trace' a plot of the trace of the residual covariance matrix versus iterations is generated. If Plot='log.det' the log(determinant) of the residual covariance matrix (resid.cov) is generated. Default is Plot= 'none'.
Check	(TRUE/FALSE) results (if TRUE) in a printout of some controls of the call to arima. Useful in the first attempt(s) to use marima. Default=FALSE.

**Value**

Object of class marima containing:

N = N length of analysed series

kvar = dimension of time series (all random and non-random variables).



ar.estimate = ar-estimate  
 ma.estimate = ma-estimate  
 ar.fvalues = ar-fvalues (approximate)  
 ma.fvalues = ma-fvalues (approximate)  
 ar.stdv = standard deviations of ar-estimate (approximate)  
 ma.stdv = standard deviations of ma-estimate (approximate)  
 ar.pvalues = ar.estimate p-values (approximate). If in the input data two series are identical or one (or more) series is (are) linearly dependent of the the other series the routine lm(...) generates "NA" for estimates t-values, p-values and parameter standard deviations. In marima the corresponding estimates, F-values and parameter standard deviations are set to 0 (zero) while the p-value(s) are set to "NaN". Can happen only for ar-parameters.  
 ma.pvalues = ma.estimate p-values (approximate)  
 residuals = estimated residuals (for used.cases), leading values (not estimated values) are put equal to NA  
 fitted = estimated/fitted values for all data (including non random variables) (for used.cases), leading values (not estimated values) are put equal to NA  
 resid.cov = covariance matrix of residuals (including non random variables) (computed for used.cases)  
 data.cov = covariance matrix of (all) input data (for used.cases)  
 averages = averages of input variables  
 Constant = estimated model constant = (sum\_i(ar[, , i])) x averages  
 call.ar.pattern = calling ar.pattern  
 call.ma.pattern = calling ma.pattern  
 out.ar.pattern = resulting ar.pattern (after possible model reduction)  
 out.ma.pattern = resulting ar.pattern (after possible model reduction)  
 max.iter = max no. of iterations in call  
 penalty = factor used in AIC model reduction, if penalty=0, no AIC model reduction is performed (default).  
 weight = weighting of successive residuals updating (default=0.33)  
 used.cases = cases in input which are analysed  
 trace = trace(random part of resid.cov)  
 log.det = log(det(random part of resid.cov))  
 randoms = which are random variables in problem?  
 one.step = one step ahead prediction (for time = N+1) based on whole series from obs. 1 to N. The computation is based on the marima residuals (as taken from the last regression step in the repeated pseudo-regression algorithm).

### Source

The code is an R code which is based on the article (below) by Spliid (1983). A repeated (socalled) pseudo regression procedure is used in order to estimate the multivariate arma model.

## References

Jenkins, G.M. & Alavi, A. (1981): Some aspects of modelling and forecasting multivariate time series, *Journal of Time Series Analysis*, Vol. 2, issue 1, Jan. 1981, pp. 1-47.

Madsen, H. (2008) *Time Series Analysis*, Chapman & Hall (in particular chapter 9: Multivariate time series).

Reinsel, G.C. (2003) *Elements of Multivariate Time Series Analysis*, Springer Verlag, 2<sup>nd</sup> ed. pp. 106-114.

Shumway, R.H. & Stoffer, D.S. (2000). *Time Series Analysis and Its Applications*, Springer Verlag, (4<sup>th</sup> ed. 2016).

Spliid, H.: A Fast Estimation Method for the Vector Autoregressive Moving Average Model With Exogenous Variables, *Journal of the American Statistical Association*, Vol. 78, No. 384, Dec. 1983, pp. 843-849.

Spliid, H.: Estimation of Multivariate Time Series with Regression Variables:

<http://www.imm.dtu.dk/~hspl/marima.use.pdf>

[www.itl.nist.gov/div898/handbook/pmc/section4/pmc45.htm](http://www.itl.nist.gov/div898/handbook/pmc/section4/pmc45.htm)

## Examples

```
# Example 1:
library(marima)
# Generate a 4-variate time series (in this example):
#
kvar<-4 ; set.seed(4711)
y4<-matrix(round(100*rnorm(4*1000, mean=2.0)), nrow=kvar)
# If wanted define differencing of variable 4 (lag=1)
# and variable 3 (lag=6), for example:
y4.dif<-define.dif(y4, difference=c(4, 1, 3, 6))
# The differenced series will be in y4.dif$y.dif, the observations
# lost by differencing being excluded.
#
y4.dif.analysis<-y4.dif$y.dif
# Give lags the be included in ar- and ma-parts of model:
#
ar<-c(1, 2, 4)
ma<-c(1)
# Define the multivariate arma model using 'define.model' procedure.
# Output from 'define.model' will be the patterns of the ar- and ma-
# parts of the model specified.
#
Mod <- define.model(kvar=4, ar=ar, ma=ma, reg.var=3)
arp<-Mod$ar.pattern
map<-Mod$ma.pattern
# Print out model in 'short form':
#
short.form(arp)
short.form(map)
# Now call marima:
Model <- marima(y4.dif.analysis, ar.pattern=arp, ma.pattern=map,
```

```

                                penalty=0.0)
# The estimated model is in the object 'Model':
#
ar.model<-Model$ar.estimateds
ma.model<-Model$ma.estimateds
dif.poly<-y4.dif$dif.poly # = difference polynomial in ar-form.
# Multiply the estimated ar-polynomial with difference polynomial
# to compute the aggregated ar-part of the arma model:
#
ar.aggregated <- pol.mul(ar.model, dif.poly, L=12)
# and print everything out in 'short form':
#
short.form(ar.aggregated, leading=FALSE)
short.form(ma.model, leading=FALSE)

```

---

marima.sim

*marima.sim*


---

### Description

Simulation of multivariate arma model of type 'marima'.

### Usage

```

marima.sim(kvar = 1, ar.model = NULL, ar.dif = NULL, ma.model = NULL,
           averages = rep(0, kvar), resid.cov = diag(kvar), seed = NULL,
           nstart = 0, nsim = 0)

```

### Arguments

kvar	dimension of one observation (from kvar-variate time series).
ar.model	array holding the autoregressive part of model, organised as in the marima\$ar.estimateds. May be empty (default = NULL) when there is no autoregressive part.
ar.dif	array holding differencing polynomial of model, typically generated by applying the function define.dif. May be empty (default = NULL) when differencing is not included.
ma.model	array holding the moving average part of model, organised as in the marima\$ma.estimateds. May be empty (default = NULL) when there is no moving average part.
averages	vector holding the kvar averages of the variables in the simulated series.
resid.cov	(kvar x kvar) innovation covariance matrix.
seed	seed for random number generator (set.seed(seed)). If the seed is set by the user, the random number generator is initialised. If seed is not set no initialisation is done.
nstart	number of extra observations in the start of the simulated series to be left out before returning. If nstart=0 in calling marima.sim a suitable value is computed (see code).
nsim	length of (final) simulated series.

**Value**

Simulated kvar variate time series of length = nsim.

**Examples**

```
library(marima)
data(austr)
old.data <- t(austr)[, 1:83]
Model2 <- define.model(kvar=7, ar=c(1), ma=c(1),
                      rem.var=c(1, 6, 7), indep=NULL)
Marima2 <- marima(old.data, means=1, ar.pattern=Model2$ar.pattern,
                 ma.pattern=Model2$ma.pattern, Check=FALSE, Plot="none", penalty=4)

resid.cov <- Marima2$resid.cov
averages <- Marima2$averages
  ar <- Marima2$ar.estimated
  ma <- Marima2$ma.estimated

N <- 1000
kvar <- 7

y.sim <- marima.sim(kvar = kvar, ar.model = ar, ma.model = ma,
                  seed = 4711, averages = averages, resid.cov = resid.cov, nsim = N)

# Now simulate from model identified by marima (model=Marima2).
# The relevant ar and ma patterns are saved in
# Marima2$out.ar.pattern and Marima2$out.ma.pattern, respectively:

Marima.sim <- marima( t(y.sim), means=1,
                   ar.pattern=Marima2$out.ar.pattern,
                   ma.pattern=Marima2$out.ma.pattern,
                   Check=FALSE, Plot="none", penalty=0)

cat("Comparison of simulation model and estimates",
    " from simulated data. \n")
  round(Marima2$ar.estimated[, , 2], 4)
  round(Marima.sim$ar.estimated[, , 2], 4)

  round(Marima2$ma.estimated[, , 2], 4)
  round(Marima.sim$ma.estimated[, , 2], 4)
```

---

pol.inv

*pol.inv*

---

**Description**

Calculation of left inverse of matrix polynomial. The leading term is expected to be the (k by k) identity matrix. This is checked and the proper leading unity term is taken into account when the inverse is calculated.

phi = matrix polynomial coefficients = I, phi1, phi2, ..., phi(p).  
 dim(phi) = c(k, k, p+1) where k = dimension of coefficient matrices (k by k), and L = order of polynomial (length = 1+L, including the leading unity matrix).

**Usage**

```
pol.inv(phi, L)
```

**Arguments**

phi	polynomium (an array) to invert
L	order of inverse polynomium

**Value**

left inverse of phi of order L (L+1 terms including leading unity matrix)

**Examples**

```
set.seed(4711)
p2<-check.one(array(rnorm(32),dim=c(4,4,2)))
pi2<-pol.inv(p2,L=12)
short.form(pi2)
```

---

pol.mul

*pol.mul*

---

**Description**

Calculation of product of two matrix polynomials (arrays).

If one or both leading unity matrices (of eta and theta) are missing, they are (it is) generated (and taken into account).

**Usage**

```
pol.mul(eta, theta, L)
```

**Arguments**

eta	first matrix polynomial
theta	second matrix polynomial
L	order of output polynomial (length = L+1)

**Value**

matrix polynomial product of eta and theta

**Examples**

```

set.seed(4711)
p1 <- check.one(matrix(rnorm(16), nrow=4))
p2 <- check.one(array(rnorm(32),dim=c(4, 4, 2)))
p12 <- pol.mul(p1, p2, L=(2+3))
short.form(p12)

```

---

`pol.order`

*pol.order*

---

**Description**

Function to evaluate (significant) order of matrix polynomial.

**Usage**

```
pol.order(polyn = NULL, digits = 12)
```

**Arguments**

<code>polyn</code>	the polynomial the order of which is determined.
<code>digits</code>	number of significant digits to be considered (values smaller than $10^{-(\text{digits})}$ are taken to be 0 (zero)).

**Value**

`pol.order` order of polynomial `polyn`. (exclusive the leading unity matrix if present. `pol.order=0` corresponds to the  $k$  by  $k$  unity matrix)

**Examples**

```

pol          <- array(1e-8*rnorm(96),dim=c(4,4,6))
pol[, , 1:3] <- array(rnorm(48), dim=c(4,4,3))
pol.order(polyn=pol, digits=12)
pol.order(polyn=pol, digits=4)

```

---

print.marima	<i>print.marima</i>
--------------	---------------------

---

**Description**

Print some (most relevant) content of a marima object.

**Usage**

```
## S3 method for class 'marima'
print(x, estimates = TRUE, pvalues = FALSE,
      pattern = TRUE, fvalues = TRUE, ...)
```

**Arguments**

x	= a marima object with results of marima analysis.
estimates	= TRUE/FALSE: printout of parameter estimates.
pvalues	= TRUE/FALSE: printout of (approximate) p-values for parameter estimates.
pattern	= TRUE/FALSE: printout of model definition pattern(s).
fvalues	= TRUE/FALSE: printout of parameter (approximate) F-values.
...	Not used.

---

rand.shock	<i>rand.shock</i>
------------	-------------------

---

**Description**

Calculation of random shock form for arma model

**Usage**

```
rand.shock(ar.poly, ma.poly, L)
```

**Arguments**

ar.poly	autoregressive matrix part of model
ma.poly	moving average matrix part of model
L	order of return polynomial (length=L+1 including leading unity matrix)

**Value**

random shock form of arma model up to order L (array(k,k,L+1))

**Examples**

```

set.seed(4711)
p1 <- check.one(matrix(rnorm(16),nrow=4))
p2 <- check.one(array(rnorm(32),dim=c(4, 4, 2)))
randshock <- rand.shock(ar.poly=p1, ma.poly=p2, L=6)
short.form(randshock)

```

---

Results

*Results*


---

**Description**

function which generates a matrix from `summary(Model)`, where 'Model' is an 'lm' object. Is used by `marima`, in case there can be one or more non-identifiable (ar-)parameters when estimating the lm-object.

**Usage**

```
Results(Model = NULL)
```

**Arguments**

`Model` = an 'lm' object (with NA's for non-identifiable ar.parameters in the 'lm' specification, if so).

**Value**

`Results` = matrix with 4 columns containing the same information as `summary(Model)`, but with "NA" rows replaced by rows = `c(0, 0, 0, NaN)`.

---

season.lagging

*season.lagging*


---

**Description**

Generate new time series with (seasonally) lagged variables from lagging pattern.

**Usage**

```
season.lagging(y, lagging = NULL)
```



**Arguments**

`y` = data series

`lagging` = lagging array array describing what to be added to `y`: `c(1, 3, 6)` adds a new `y3`, using `y1` lagged 6 time steps. `lagging<-matrix(c(1, 3, 6-1, 2, 4, 12-1), nrow=3)` adds two new variables (`y3` and `y4`) using `y1` lagged 6-1 time steps and `y2` lagged 12-1 time steps.

**Value**

`y.lagged` = the part of the new series (including new lagged variables) that can be entered into `marima`

`y.future` = the part of the new series (including new lagged variables) that does not include future observation

`y.lost` = previous values of the time series that is incomplete with respect to the new variables generated by lagging

`cbind(y.lost, y.lagged.y, y.future)` is the complete series after creation and addition of the lagged variables.

**Examples**

```
set.seed(4711)
# generate bivariate time series
y<-round(matrix(10*rnorm(36), nrow=2))
y
# define new lagged variables (y3 and y4) with seasonalities 6 and 12
lagging <- c(1, 3, (6-1), 2, 4, (12-1))
season.lagging(y, lagging)
```

---

short.form

*short.form*


---

**Description**

Function to condensate (and/or) print out matrix polynomial leaving out empty lag matrices and, if specified, the leading (unity) matrix.

**Usage**

```
short.form(poly = NULL, name = "Lag=", leading = TRUE, tail = FALSE,
  digits = 6)
```

**Arguments**

poly	matrix polynomial (0-1 array as constructed by define.model, for example, or array of reals as estimated by marima).
name	character string used as header in output (default='lag').
leading	TRUE/FALSE. If leading=FALSE the leading (unity matrix) is to be left out/suppressed.
tail	TRUE/FALSE. If TRUE and the ar/ma-model only consists of coefficient matrix(s) where all coefficients (except the leading unity matrix) are all zero a first order coefficient matrix (being zero) is retained (in order to avoid a model containing only the leading unity matrix). If tail=TRUE and the coefficients in the first coefficient matrix (after the leading unity matrix) are all zero, the leading unity matrix is always retained.
digits	the number of digits retained by short.form (default=6).

**Examples**

```

Model<-define.model(kvar=4, ar=c(1, 2, 4), ma=c(1), reg.var=4)
short.form(Model$ar.pattern)
short.form(Model$ma.pattern)
short.form(Model$ar.pattern, leading=FALSE)
short.form(Model$ar.pattern, leading=FALSE)
#
M<-define.model(kvar=4, ma=c(1))
short.form(M$ar.pattern)
short.form(M$ar.pattern, tail=TRUE)
short.form(M$ar.pattern, leading=FALSE, tail=TRUE)

```

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