Package ‘MFDFA’

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Type Package

Title MultiFractal Detrended Fluctuation Analysis

Version 1.0

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Description Applies the MultiFractal Detrended Fluctuation Analysis (MFDFA) to time series. The MFDFA() function proposed in this package was used in Laib et al. (<doi:10.1016/j.chaos.2018.02.024> and <doi:10.1063/1.5022737>). See references for more information.

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URL https://mlaib.github.io

Note The originale code was in matlab, see details below.

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MFDFA *MultiFractal Detrended Fluctuation Analysis*

Description

Applies the MultiFractal Detrended Fluctuation Analysis (MFDFA) to time series.

Usage

```
MFDFA(tsx, scale, m=1, q)
```

Arguments

`tsx`	Univariate time series (must be a vector).
`scale`	Vector of scales. There is no default value for this parameter, please add values.
`m`	Polynomial order for the detrending (by defaults m=1).
`q`	q-order of the moment. There is no default value for this parameter, please add values.

Details

The original code of this function is in Matlab, you can find it on the following website Mathworks.

Value

A list of the following elements:

- `Hq` Hurst exponent.
- `tau_q` Mass exponent.
- `spec` Multifractal spectrum (α and $f(\alpha)$)
- `Fq` Fluctuation function.

References

J. Feder, Fractals, Plenum Press, New York, NY, USA, 1988.

Espen A. F. Ihlen, Introduction to multifractal detrended fluctuation analysis in matlab, Frontiers in Physiology: Fractal Physiology, 3 (141),(2012) 1-18.

J. W. Kantelhardt, S. A. Zschiegner, E. Koscielny-Bunde, S. Havlin, A. Bunde, H. Stanley, Multifractal detrended fluctuation analysis of nonstationary time series, Physica A: Statistical Mechanics and its Applications, 316 (1) (2002) 87 – 114.

M. Laib, L. Telesca and M. Kanevski, Long-range fluctuations and multifractality in connectivity density time series of a wind speed monitoring network, Chaos: An Interdisciplinary Journal of Nonlinear Science, 28 (2018) p. 033108, Paper.

M. Laib, J. Golay, L. Telesca, M. Kanevski, Multifractal analysis of the time series of daily means of wind speed in complex regions, Chaos, Solitons & Fractals, 109 (2018) pp. 118-127, Paper.

Examples

```
## Not run:
## MFDFA package installation: from github ####

install.packages("devtools")

devtools::install_github("mlaib/MFDFA")

## End(Not run)
library(MFDFA)

a<-0.9
N<-1024
tsx<-MFsim(N,a)

scale=10:100
q<--10:10
m<-1
mfdfa<-MFDFA(tsx, scale, m, q)

## Not run:
## Results plot ####
dev.new()
par(mai=rep(1, 4))
plot(q, mfdfa$Hq, col=1, axes= F, ylab=expression('h'[q]), pch=16, cex.lab=1.8,
     cex.axis=1.8, main="Hurst exponent",
     ylim=c(min(mfdfa$Hq),max(mfdfa$Hq)))
grid(col="midnightblue")
axis(1)
axis(2)

##################################
## Suggestion of output plot: ####
##################################

##################################
## Supplementary functions: #####
reset <- function(){
par(mfrow=c(1, 1), oma=rep(0, 4), mar=rep(0, 4), new=TRUE)
plot(0:1, 0:1, type="n", xlab="", ylab="", axes=FALSE)}

poly_fit<-function(x,y,n){
  formule<-lm(as.formula(paste('y~',paste('I(x^',1:n,')', sep='',collapse='+'))))
  res1<-coef(formule)
  poly.res<-res1[length(res1):1]
  allres<-list(polyfit=poly.res, model1=formule)
  return(allres)}
##################################

##################################
## Output plots: #################
```

```
dev.new()
layout(matrix(c(1,2,3,4), 2, 2, byrow = TRUE),heights=c(4, 4))
## b : mfdfa output
par(mai=rep(0.8, 4))
## 1st plot: Scaling function order Fq (q-order RMS)
p1<-c(1,which(q==0),which(q==q[length(q)]))
plot(log2(scale),log2(b$Fqi[,1]),  pch=16, col=1, axes = F, xlab = "s (days)",
     ylab=expression('log'[2]*'(F'[q]*')'), cex=1, cex.lab=1.6, cex.axis=1.6,
     main= "Fluctuation functionFq",
     ylim=c(min(log2(b$Fqi[,c(p1)])),max(log2(b$Fqi[,c(p1)]))))

lines(log2(scale),b$line[,1], type="l", col=1, lwd=2)
grid(col="midnightblue")
axis(2)
lbl<-scale[c(1,floor(length(scale)/8),floor(length(scale)/4),
             floor(length(scale)/2),length(scale))]
att<-log2(lbl)
axis(1, at=att, labels=lbl)
for (i in 2:3){
  k<-p1[i]
  points(log2(scale), log2(b$Fqi[,k]),  col=i,pch=16)
  lines(log2(scale),b$line[,k], type="l", col=i, lwd=2)
}

legend("bottomright", c(paste('q','=',q[p1] , sep=' ' )),cex=2,lwd=c(2,2,2),
 bty="n", col=1:3)



## 2nd plot: q-order Hurst exponent

plot(q, b$Hq, col=1, axes= F, ylab=expression('h'[q]), pch=16, cex.lab=1.8,
    cex.axis=1.8, main="Hurst exponent", ylim=c(min(b$Hq),max(b$Hq)))
grid(col="midnightblue")
axis(1, cex=4)
axis(2, cex=4)

## 3rd plot: q-order Mass exponent
plot(q, b$tau_q, col=1, axes=F, cex.lab=1.8, cex.axis=1.8,
     main="Mass exponent",
     pch=16,ylab=expression(tau[q]))

grid(col="midnightblue")
axis(1, cex=4)
axis(2, cex=4)


## 4th plot: Multifractal spectrum

plot(b$spec$hq, b$spec$Dq, col=1, axes=F, pch=16, #main="Multifractal spectrum",
     ylab=bquote("f ("~alpha~")"),cex.lab=1.8, cex.axis=1.8,
     xlab=bquote(~alpha))
```

```
grid(col="midnightblue")
axis(1, cex=4)
axis(2, cex=4)

x1=b$spec$hq
y1=b$spec$Dq
rr<-poly_fit(x1,y1,4)
mm1<-rr$model1
mm<-rr$polyfit
x2<-seq(0,max(x1)+1,0.01)
curv<-mm[1]*x2^4+mm[2]*x2^3+mm[3]*x2^2+mm[4]*x2+mm[5]
lines(x2,curv, col="red", lwd=2)
reset()
legend("top", legend="MFDFA Plots", bty="n", cex=2)

## End(Not run)
```

`MFsim` *Simulated multifractal series.*

Description

Generates series using the binomial multifractal model (see references).

Usage

```
MFsim(N,a)
```

Arguments

`N`	The length of the generated multifractal series.
`a`	The Hurst exponent, which takes values in [0.5, 1].

Value

A vector containing the multifractal series

References

J. Feder, Fractals, Plenum Press, New York, NY, USA, 1988.

E.L. Flores-Márquez, A. Ramírez-Rojas, L. Telesca, Multifractal detrended fluctuation analysis of earthquake magnitude series of Mexican South Pacific Region, Applied Mathematics and Computation, Volume 265, 2015, Pages 1106-1114, ISSN 0096-3003.

Examples

```
a<-0.9
N<-1024
tsx<-MFsim(N,a)

scale=10:100
q<--10:10
m<-1
b<-MFDFA(tsx, scale, m, q)
dev.new()
par(mai=rep(1, 4))
plot(q, b$Hq, col=1, axes= FALSE, ylab=expression('h'[q]), pch=16, cex.lab=1.8,
     cex.axis=1.8, main="q-order Hurst exponent", ylim=c(min(b$Hq),max(b$Hq)))
grid(col="midnightblue")
axis(1)
axis(2)
```

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