Package ‘NMOF’

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**Type**  Package

**Title**  Numerical Methods and Optimization in Finance

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**Maintainer**  Enrico Schumann <es@enricoschumann.net>

**Depends**  R (>= 2.14)

**Imports**  grDevices, graphics, parallel, stats, utils

**Suggests**  MASS, PMwR, RUnit, Rglpk, datetimeutils, openxlsx, quadprog, readxl, tinytest

**Description**  Functions, examples and data from the first and the second edition of “Numerical Methods and Optimization in Finance” by M. Gilli, D. Maringer and E. Schumann (2019, ISBN:978-0128150658). The package provides implementations of optimisation heuristics (Differential Evolution, Genetic Algorithms, Particle Swarm Optimisation, Simulated Annealing and Threshold Accepting), and other optimisation tools, such as grid search and greedy search. There are also functions for the valuation of financial instruments such as bonds and options, for portfolio selection and functions that help with stochastic simulations.

**License**  GPL-3


**LazyLoad**  yes

**LazyData**  yes

**ByteCompile**  yes

**Classification/JEL**  C61, C63

**NeedsCompilation**  no

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**Repository**  CRAN

**Date/Publication**  2021-10-20 09:10:02 UTC
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Description

Functions, data and other \texttt{R} code from the book ‘Numerical Methods and Optimization in Finance’. Comments/corrections/remarks/suggestions are very welcome (please contact the maintainer directly).

Details

The package contains implementations of several optimisation heuristics: Differential Evolution (\texttt{DEopt}), Genetic Algorithms (\texttt{GAopt}), (Stochastic) Local Search (\texttt{LSopt}), Particle Swarm (\texttt{PSopt}), Simulated Annealing (\texttt{SAopt}) and Threshold Accepting (\texttt{TAopt}). The term heuristic is meant in the sense of general-purpose optimisation method.

Dependencies: The package is completely written in \texttt{R}. A number of packages are suggested, but they are not strictly required when using the \texttt{NMOF} package, and most of the package’s functionality is available without them. Specifically, package \texttt{MASS} is needed to run the complete example for \texttt{PSopt} and also in one of the vignettes (\texttt{PSlms}). Package \texttt{parallel} is optional for functions \texttt{bracketing}, \texttt{GAopt}, \texttt{gridSearch} and \texttt{restartOpt}, and may become an option for other functions. Package \texttt{quadprog} is needed for a vignette (\texttt{TAportfolio}), some tests, and it may be used for computing mean-variance efficient portfolios. Package \texttt{Rglpk} is needed for function \texttt{minCVaR}. Package \texttt{readxl} is needed to process the raw data in function \texttt{Shiller}; package \texttt{datetimeutils} is used by \texttt{French} and \texttt{Shiller}. PMwR would be needed to run the examples of the backtesting examples in the NMOF book. Finally, packages \texttt{RUnit} and \texttt{tinytest} are needed to run the tests in subdirectory ‘unitTests’.

Version numbering: package versions are numbered in the form major-minor-patch. The patch level is incremented with any published change in a version. Minor version numbers are incremented when a feature is added or an existing feature is substantially revised. (Such changes will be reported in the NEWS file.) The major version number will only be increased if there were a new edition of the book.

The source code of the \texttt{NMOF} package is also hosted at \url{https://github.com/enricoschumann/NMOF/}. Updates to the package and new features are described at \url{http://enricoschumann.net/notes/NMOF/}.

Optimisation:

There are functions for Differential Evolution (\texttt{DEopt}), Genetic Algorithms (\texttt{GAopt}), (Stochastic) Local Search (\texttt{LSopt}), Simulated Annealing (\texttt{SAopt}), Particle Swarm (\texttt{SAopt}), and Threshold Accepting (\texttt{TAopt}). The function \texttt{restartOpt} helps with running restarts of these methods; also available are functions for grid search (\texttt{gridSearch}) and greedy search (\texttt{greedySearch}).
Pricing Financial Instruments:
For options: See vanillaOptionEuropean, vanillaOptionAmerican, putCallParity. For pricing methods that use the characteristic function, see callCF.
For bonds and bond futures: See vanillaBond, bundFuture and xtContractValue.

Simulation:
See resampleC and mc.

Data:
See bundData, fundData and optionData.

Author(s)
Enrico Schumann
Maintainer: Enrico Schumann <es@enricoschumann.net>

References

Examples
## Not run:
library("NMOF")

## overview
packageDescription("NMOF")
help(package = "NMOF")

## code from book
showExample("equations.R")
showExample("exampleLS.R", chapter = 13)

## show NEWS file
news(Version >= "1.0-0", package = "NMOF")

## vignettes
vignette(package = "NMOF")
nss <- vignette("DEnss", package = "NMOF")
print(nss)
edit(nss)

## book website
browseURL("http://nmof.net")
browseURL("http://enricoschumann.net/NMOF/")
## package websites
browseURL("http://enricoschumann.net/R/packages/NMOF/"
browseURL("https://cran.r-project.org/package=NMOF")
browseURL("https://github.com/enricoschumann/NMOF")

## unit tests
file.show(system.file("unitTests/test_results.txt", package = "NMOF"))

## End(Not run)
test.rep <- readLines(system.file("unitTests/test_results.txt", 
package = "NMOF"))
nt <- gsub(".*\((\[0-9]+) checks?\).*", \1,
test.rep[grep("(\d+ checks?)", test.rep)])
message("Number of unit tests: ", sum(as.numeric(nt)))

---

**bracketing**

**Zero-Bracketing**

### Description
Bracket the zeros (roots) of a univariate function

### Usage
```
bracketing(fun, interval, ..., 
lower = min(interval), upper = max(interval), 
n = 20L, 
method = c("loop", "vectorised", "multicore", "snow"), 
mc.control = list(), cl = NULL)
```

### Arguments
- **fun**: a univariate function; it will be called as `fun(x,...)` with `x` being a numeric vector
- **interval**: a numeric vector, containing the end-points of the interval to be searched
- **...**: further arguments passed to `fun`
- **lower**: lower end-point. Ignored if `interval` is specified.
- **upper**: upper end-point. Ignored if `interval` is specified.
- **n**: the number of function evaluations. Must be at least 2 (in which case `fun` is evaluated only at the end-points); defaults to 20.
- **method**: can be `loop` (the default), `vectorised`, `multicore` or `snow`. See Details.
- **mc.control**: a list containing settings that will be passed to `mclapply` if `method` is `multicore`. Must be a list of named elements. See the documentation of `mclapply` in package `parallel`.
- **cl**: default is `NULL`. If `method` is `snow`, this must be a cluster object or an integer (the number of cores to be used). See the documentation of packages `parallel` and `snow`. 
Details

`bracketing` evaluates `fun` at equal-spaced values of `x` between (and including) `lower` and `upper`. If the sign of `fun` changes between two consecutive `x`-values, `bracketing` reports these two `x`-values as containing (‘bracketing’) a root. There is no guarantee that there is only one root within a reported interval. `bracketing` will not narrow the chosen intervals.

The argument `method` determines how `fun` is evaluated. Default is `loop`. If `method` is "vectorised", `fun` must be written such that it can be evaluated for a vector `x` (see Examples). If `method` is `multicore`, function `mclapply` from package `parallel` is used. Further settings for `mclapply` can be passed through the list `mc.control`. If `multicore` is chosen but the functionality is not available (eg, currently on Windows), then `method` will be set to `loop` and a warning is issued. If `method` is `snow`, function `clusterApply` from package `parallel` is used. In this case, the argument `cl` must either be a cluster object (see the documentation of `clusterApply`) or an integer. If an integer, a cluster will be set up via `makeCluster(c(rep("localhost",cl)),type = "SOCK");` and `stopCluster` is called when the function is exited. If `snow` is chosen but the package is not available or `cl` is not specified, then `method` will be set to `loop` and a warning is issued. In case that `cl` is a cluster object, `stopCluster` will not be called automatically.

Value

A numeric matrix with two columns, named `lower` and `upper`. Each row contains one interval that contains at least one root. If no roots were found, the matrix has zero rows.

Author(s)

Enrico Schumann

References


See Also

`uniroot` (in package `stats`)

Examples

```r
# Gilli/Maringer/Schumann (2011), p. 290
testFun <- function(x)
  cos(1/x^2)

bracketing(testFun, interval = c(0.3, 0.9), n = 26L)
bracketing(testFun, interval = c(0.3, 0.9), n = 26L, method = "vectorised")
```
German Government Bond Data

Description
A sample of data on 44 German government bonds. Contains ISIN, coupon, maturity and dirty price as of 2010-05-31.

Usage
bundData

Format
bundData is a list with three components: cfList, tmList and bM. cfList is list of 44 numeric vectors (the cash flows). tmList is a list of 44 character vectors (the payment dates) formatted as YYYY-MM-DD. bM is a numeric vector with 44 elements (the dirty prices of the bonds).

Details
All prices are as of 31 May 2010. See chapter 14 in Gilli et al. (2011).

Source
The data was obtained from https://www.deutsche-finanzagentur.de/en/. The data is also freely available from the website of the Bundesbank https://www.bundesbank.de/en/.

References


Examples
bundData
str(bundData)

## get ISINs of bonds
names(bundData$cfList)

## get a specific bond
thisBond <- "DE0001135358"
data.frame(dates = as.Date(bundData$tmList[[thisBond]]),
           payments = bundData$cfList[[thisBond]])
bundFuture

Theoretical Valuation of Euro Bund Future

Description
Compute theoretical prices of bund future.

Usage

bundFuture(clean, coupon, trade.date,
    expiry.date, last.coupon.date,
    r, cf)

bundFutureImpliedRate(future, clean, coupon,
    trade.date, expiry.date,
    last.coupon.date, cf)

Arguments

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<tr>
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<th>Description</th>
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</tr>
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</tr>
<tr>
<td>r</td>
<td>numeric: 0.01</td>
</tr>
<tr>
<td>cf</td>
<td>numeric: conversion factor of CTD</td>
</tr>
</tbody>
</table>

Details

bundFuture computes the theoretical prices of the Bund Future, given the prices of the cheapest-to-deliver eligible government bond.

bundFutureImpliedRate computes the implied refinancing rate.

Value
numeric

Author(s)

Enrico Schumann
References


Examples

## Bund-Future with expiry Sep 2017
## CTD: DE0001102408 -- 0%, 15 Aug 2026
##
## On 21 August 2017, the CTD traded (clean) at 97.769
## the FGBL Sep 2017 closed at 164.44.

```r
bundFuture(clean = 97.769,  ## DE0001102408
            coupon = 0,
            trade.date = "2017-8-21",
            expiry.date = "2017-09-07",  ## Bund expiry
            last.coupon.date = "2017-08-15",  ## last co
            r = -0.0037,
            cf = 0.594455)  ## conversion factor (from Eurex website)
```

```r
bundFutureImpliedRate(future = 164.44,
                       clean = 97.769,
                       coupon = 0,
                       trade.date = "2017-8-21",
                       expiry.date = "2017-09-07",
                       last.coupon.date = "2017-08-15",
                       cf = 0.594455)
```

callCF

Price a Plain-Vanilla Call with the Characteristic Function

Description

Price a European plain-vanilla call with the characteristic function.

Usage

```r
callCF(cf, S, X, tau, r, q = 0, ...,  
implVol = FALSE, unirroot.control = list(), unirroot.info = FALSE)
cfBSM(om, S, tau, r, q, v)
cfMerton(om, S, tau, r, q, v, lambda, muJ, vJ)
cfBates(om, S, tau, r, q, v0, vT, rho, k, sigma, lambda, muJ, vJ)
cfHeston(om, S, tau, r, q, v0, vT, rho, k, sigma)
cfVG(om, S, tau, r, q, nu, theta, sigma)
```
Arguments

- **cf**: characteristic function
- **S**: spot
- **X**: strike
- **tau**: time to maturity
- **r**: the interest rate
- **q**: the dividend rate
- ... arguments passed to the characteristic function
- **implVol**: logical: compute implied vol?

**uniroot.control**

A list. If there are elements named interval, tol or maxiter, these are passed to uniroot. Any other elements of the list are ignored.

**uniroot.info**

logical; default is FALSE. If TRUE, the function will return the information returned by uniroot. See paragraph Value below.

- **om**: a (usually complex) argument
- **v0**: a numeric vector of length one
- **vT**: a numeric vector of length one
- **v**: a numeric vector of length one
- **rho**: a numeric vector of length one
- **k**: a numeric vector of length one
- **sigma**: a numeric vector of length one
- **lambda**: a numeric vector of length one
- **muJ**: a numeric vector of length one
- **vJ**: a numeric vector of length one
- **nu**: a numeric vector of length one
- **theta**: a numeric vector of length one

Details

The function computes the value of a plain vanilla European call under different models, using the representation of Bakshi/Madan. Put values can be computed through put–call parity (see `putCallParity`).

If `implVol` is TRUE, the function will compute the implied volatility necessary to obtain the same value under Black–Scholes–Merton. The implied volatility is computed with `uniroot` from the `stats` package. The default search interval is `c(0.00001, 2)`; it can be changed through `uniroot.control`.

The function uses variances as inputs (not volatilities).

The function is not vectorised (but see the NMOF Manual for examples of how to efficiently price more than one option at once).
callCF

Value

Returns the value of the call (numeric) under the respective model or, if implVol is TRUE, a list of the value and the implied volatility. (If, in addition, uniroot.info is TRUE, the information provided by uniroot is also returned.)

Note

If implVol is TRUE, the function will return a list with elements named value and impliedVol. Prior to version 0.26-3, the first element was named callPrice.

Author(s)

Enrico Schumann

References


See Also

callHestoncf

Examples

```r
S <- 100; X <- 100; tau <- 1
r <- 0.02; q <- 0.08
v0 <- 0.2^2  ## variance, not volatility
vT <- 0.2^2  ## variance, not volatility
v <- vT
rho <- -0.3; k <- .2
sigma <- 0.3

## jump parameters (Merton and Bates)
lambda <- 0.1
muJ <- -0.2
vJ <- 0.1^2

## get Heston price and BSM implied volatility
callHestoncf(S, X, tau, r, q, v0, vT, rho, k, sigma, implVol = FALSE)
callCF(cf = cfHeston, S=S, X=X, tau=tau, r=r, q = q,
  v0 = v0, vT = vT, rho = rho, k = k, sigma = sigma, implVol = FALSE)
```
## Black-Scholes-Merton

```r
callCF(cf = cfBSM, S=S, X=X, tau = tau, r = r, q = q,
v = v, implVol = TRUE)
```

## Bates

```r
callCF(cf = cfBates, S = S, X = X, tau = tau, r = r, q = q,
v0 = v0, vT = vT, rho = rho, k = k, sigma = sigma,
lambda = lambda, muJ = muJ, vJ = vJ, implVol = FALSE)
```

## Merton

```r
callCF(cf = cfMerton, S = S, X = X, tau = tau, r = r, q = q,
v = v, lambda = lambda, muJ = muJ, vJ = vJ, implVol = FALSE)
```

## variance gamma

```r
nu <- 0.1; theta <- -0.1; sigma <- 0.15
callCF(cf = cfVG, S = S, X = X, tau = tau, r = r, q = q,
nu = nu, theta = theta, sigma = sigma, implVol = FALSE)
```

### callHestoncf

**Price of a European Call under the Heston Model**

#### Description

Computes the price of a European Call under the Heston model (and the equivalent Black–Scholes–Merton volatility)

#### Usage

```r
callHestoncf(S, X, tau, r, q, v0, vT, rho, k, sigma, implVol = FALSE, ...)
```

#### Arguments

- `S`: current stock price
- `X`: strike price
- `tau`: time to maturity
- `r`: risk-free rate
- `q`: dividend rate
- `v0`: current variance
- `vT`: long-run variance
- `rho`: correlation between spot and variance
- `k`: speed of mean-reversion
- `sigma`: volatility of variance. A value smaller than 0.01 is replaced with 0.01.
- `...`: named arguments, passed to `integrate`
Details

The function computes the value of a plain vanilla European call under the Heston model. Put values can be computed through put–call-parity. If \texttt{implVol} is \texttt{TRUE}, the function will compute the implied volatility necessary to obtain the same price under Black–Scholes–Merton. The implied volatility is computed with \texttt{uniroot} from the \texttt{stats} package.

Note that the function takes variances as inputs (not volatilities).

Value

Returns the value of the call (numeric) under the Heston model or, if \texttt{implVol} is \texttt{TRUE}, a list of the value and the implied volatility.

Note

If \texttt{implVol} is \texttt{TRUE}, the function will return a list with elements named \texttt{value} and \texttt{impliedVol}.

Prior to version 0.26-3, the first element was named \texttt{callPrice}.

Author(s)

Enrico Schumann

References


See Also

callCF, EuropeanCall

Examples

```r
S <- 100; X <- 100; tau <- 1; r <- 0.02; q <- 0.01
v0 <- 0.2^2  ## variance, not volatility
vT <- 0.2^2  ## variance, not volatility
rho <- -0.7; k <- 0.2; sigma <- 0.5

## get Heston price and BSM implied volatility
result <- callHestoncf(S = S, X = X, tau = tau, r = r, q = q,
v0 = v0, vT = vT, rho = rho, k = k,
sigma = sigma, implVol = TRUE)

## Heston price
result[[1L]]
```
## Price BSM with implied volatility

```r
callMerton

## should be (about) the same as result[[1L]]
```
**callMerton**

**Value**

Returns the value of the call (numeric) or, if `implVol` is TRUE, a list of the value and the implied volatility.

**Author(s)**

Enrico Schumann

**References**


**See Also**

callCF, EuropeanCall

**Examples**

```r
S <- 100; X <- 100; tau <- 1
r <- 0.0075; q <- 0.00
v <- 0.2^2
lambda <- 1; muJ <- -0.2; vJ <- 0.6^2
N <- 20

## jumps can make a difference
callMerton(S, X, tau, r, q, v, lambda, muJ, vJ, N, implVol = TRUE)
callCF(cf = cfMerton, S = S, X = X, tau = tau, r = r, q = q, v = v, lambda = lambda, muJ = muJ, vJ = vJ, implVol = TRUE)
vanillaOptionEuropean(S,X,tau,r,q,v, greeks = FALSE)
lambda <- 0 ## no jumps
callMerton(S, X, tau, r, q, v, lambda, muJ, vJ, N, implVol = FALSE)
v vanillaOptionEuropean(S,X,tau,r,q,v, greeks = FALSE)
lambda <- 1; muJ <- 0; vJ <- 0.0^2 ## no jumps, either
callMerton(S, X, tau, r, q, v, lambda, muJ, vJ, N, implVol = FALSE)
v vanillaOptionEuropean(S,X,tau,r,q,v, greeks = FALSE)
```
colSubset  

Full-rank Column Subset

Description
Select a full-rank subset of columns of a matrix.

Usage
\texttt{colSubset(x)}

Arguments
\texttt{x}  a numeric matrix

Details
Uses \texttt{qr}.

Value
A list:
\begin{itemize}
  \item \texttt{columns}  indices of columns
  \item \texttt{multiplier}  a matrix
\end{itemize}

Author(s)
Enrico Schumann

References


See Also
\texttt{repairMatrix}
Examples

nc <- 3  # columns
nr <- 10 # rows
M <- array(rnorm(nr * nc), dim = c(nr, nc))

C <- array(0.5, dim = c(nc, nc))
diag(C) <- 1
M <- M %*% chol(C)
M <- M[, c(1, 1, 1, 2, 3)]
M

(tmp <- colSubset(M))

C <- cor(M[, tmp$columns])
c <- rnc
nc <- ncol(C)
X <- array(rnorm(nr * nc), dim = c(nr, nc))
X <- X %*% chol(C)
X <- X %*% tmp$multiplier
head(X)
cor(X)

<table>
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<th>CPPI</th>
<th>Constant-Proportion Portfolio Insurance</th>
</tr>
</thead>
</table>

Description

Simulate constant-proportion portfolio insurance (CPPI) for a given price path.

Usage

CPPI(S, multiplier, floor, r, tau = 1, gap = 1)

Arguments

- **S**: numeric: price path of risky asset
- **multiplier**: numeric
- **floor**: numeric: a percentage, should be smaller than 1
- **r**: numeric: interest rate (per time period tau)
- **tau**: numeric: time periods
- **gap**: numeric: how often to rebalance. 1 means every timestep, 2 means every second timestep, and so on.

Details

Based on Dietmar Maringer’s MATLAB code (function CPPIgap, Listing 9.1).
See Gilli, Maringer and Schumann, 2011, chapter 9.
Value

A list:

- `V` normalised value (always starts at 1)
- `C` cushion
- `B` bond investment
- `F` floor
- `E` exposure
- `N` units of risky asset
- `S` price path

Author(s)

Original MATLAB code: Dietmar Maringer. R implementation: Enrico Schumann.

References


Examples

```r
tau <- 2
S <- gbm(npaths = 1, timesteps = tau*256,
          r = 0.02, v = 0.2^2, tau = tau, S0 = 100)

## rebalancing every day
sol <- CPPI(S, multiplier = 5, floor = 0.9, r = 0.01,
            tau = tau, gap = 1)
par(mfrow = c(3,1), mar = c(3,3,1,1))
plot(0:(length(S)-1), S, type = "s", main = "stock price")
plot(0:(length(S)-1), sol$V, type = "s", main = "value")
plot(0:(length(S)-1), 100*sol$E/sol$V, type = "s",
     main = "% invested in risky asset")

## rebalancing every 5th day
sol <- CPPI(S, multiplier = 5, floor = 0.9, r = 0.01,
            tau = tau, gap = 5)
par(mfrow = c(3,1), mar = c(3,3,1,1))
plot(0:(length(S)-1), S, type = "s", main = "stock price")
plot(0:(length(S)-1), sol$V, type = "s", main = "value")
plot(0:(length(S)-1), 100*sol$E/sol$V, type = "s",
     main = "% invested in risky asset")
```
**Description**

The function implements the standard Differential Evolution algorithm.

**Usage**

```r
DEopt(OF, algo = list(), ...)
```

**Arguments**

- **OF**
  - The objective function, to be minimised. See Details.
- **algo**
  - A list with the settings for algorithm. See Details and Examples.
- **...**
  - Other pieces of data required to evaluate the objective function. See Details and Examples.

**Details**

The function implements the standard Differential Evolution (no jittering or other features). Differential Evolution (DE) is a population-based optimisation heuristic proposed by Storn and Price (1997). DE evolves several solutions (collected in the ‘population’) over a number of iterations (‘generations’). In a given generation, new solutions are created and evaluated; better solutions replace inferior ones in the population. Finally, the best solution of the population is returned. See the references for more details on the mechanisms.

To allow for constraints, the evaluation works as follows: after a new solution is created, it is (i) repaired, (ii) evaluated through the objective function, (iii) penalised. Step (ii) is done by a call to `OF`; steps (i) and (iii) by calls to `algo$repair` and `algo$pen`. Step (i) and (iii) are optional, so the respective functions default to `NULL`. A penalty is a positive number added to the ‘clean’ objective function value, so it can also be directly written in the `OF`. Writing a separate penalty function is often clearer; it can be more efficient if either only the objective function or only the penalty function can be vectorised. (Constraints can also be added without these mechanisms. Solutions that violate constraints can, for instance, be mapped to feasible solutions, but without actually changing them. See Maringer and Oyewumi, 2007, for an example.)

Conceptually, DE consists of two loops: one loop across the generations and, in any given generation, one loop across the solutions. `DEopt` indeed uses, as the default, two loops. But it does not matter in what order the solutions are evaluated (or repaired or penalised), so the second loop can be vectorised. This is controlled by the variables `algo$loopOF`, `algo$loopRepair` and `algo$loopPen`, which all default to `TRUE`. Examples are given in the vignettes and in the book. The respective `algo$loopFun` must then be set to `FALSE`.

All objects that are passed through `...` will be passed to the objective function, to the repair function and to the penalty function.

The list `algo` collects the the settings for the algorithm. Strictly necessary are only `min` and `max` (to initialise the population). Here are all possible arguments:
CR  probability for crossover. Defaults to 0.9. Using default settings may not be a good idea.

F  The step size. Typically a numeric vector of length one; default is 0.5. Using default settings may not be a good idea. (F can also be a vector with different values for each decision variable.)

nP  population size. Defaults to 50. Using default settings may not be a good idea.

nG  number of generations. Defaults to 300. Using default settings may not be a good idea.

min, max  vectors of minimum and maximum parameter values. The vectors min and max are used to determine the dimension of the problem and to randomly initialise the population. Per default, they are no constraints: a solution may well be outside these limits. Only if algo$minmaxConstr is TRUE will the algorithm repair solutions outside the min and max range.

minmaxConstr  if TRUE, algo$min and algo$max are considered constraints. Default is FALSE.

pen  a penalty function. Default is NULL (no penalty).

initP  optional: the initial population. A matrix of size length(algo$min) times algo$nP, or a function that creates such a matrix. If a function, it should take no arguments.

repair  a repair function. Default is NULL (no repairing).

loopOF  logical. Should the OF be evaluated through a loop? Defaults to TRUE.

loopPen  logical. Should the penalty function (if specified) be evaluated through a loop? Defaults to TRUE.

loopRepair  logical. Should the repair function (if specified) be evaluated through a loop? Defaults to TRUE.

printDetail  If TRUE (the default), information is printed. If an integer i greater then one, information is printed at very i-th generation.

printBar  If TRUE (the default), a txtProgressBar is printed.

storeF  if TRUE (the default), the objective function values for every solution in every generation are stored and returned as matrix Fmat.

storeSolutions  default is FALSE. If TRUE, the solutions (ie, decision variables) in every generation are stored and returned as a list P in list xlist (see Value section below). To check, for instance, the solutions at the end of the 1th generation, retrieve xlist[[c(1L,1)]]]. This will be a matrix of size length(algo$min) times algo$nP. (To be consistent with other functions, xlist is itself a list. In the case of DEopt, it contains just one element.)

classify  Logical; default is FALSE. If TRUE, the result will have a class attribute TAopt attached. This feature is experimental: the supported methods may change without warning.

drop  If FALSE (the default), the dimension is not dropped from a single solution when it is passed to a function. (That is, the function will receive a single-column matrix.)

Value

A list:

xbest  the solution (the best member of the population), which is a numeric vector

OFvalue  objective function value of best solution

popF  a vector. The objective function values in the final population.

Fmat  if algo$storeF is TRUE, a matrix of size algo$nG times algo$nP containing the objective function values of all solutions over the generations; else NA.
DEopt

xlist if algo@storeSolutions is TRUE, a list that contains a list P of matrices and a matrix initP (the initial solution); else NA.

initial.state the value of .Random.seed when the function was called.

Author(s)

Enrico Schumann

References


See Also

GAopt, PSopt

Examples

## Example 1: Trefethen's 100-digit challenge (problem 4)
## http://people.maths.ox.ac.uk/~trefethen/hundred.html

OF <- tfTrefethen ### see ?testFunctions
algo <- list(nP = 50L, ### population size
             nG = 300L, ### number of generations
             F = 0.6, ### step size
             CR = 0.9, ### prob of crossover
             min = c(-10, -10), ### range for initial population
             max = c(10, 10))

sol <- DEopt(OF = OF, algo = algo)
## correct answer: -3.30686864747523
format(sol$OFvalue, digits = 12)
## check convergence of population
sd(sol$popF)
ts.plot(sol$Fmat, xlab = "generations", ylab = "OF")

## Example 2: vectorising the evaluation of the population

OF <- tfRosenbrock ### see ?testFunctions
size <- 3L ### define dimension
x <- rep.int(1, size)  ### the known solution ...
OF(x)  ### ... should give zero

algo <- list(printBar = FALSE,  
              nP = 30L,  
              nG = 300L,  
              F = 0.6,  
              CR = 0.9,  
              min = rep(-100, size),  
              max = rep(100, size))

## run DEopt
(t1 <- system.time(sol <- DEopt(OF = OF, algo = algo)))
sol$xbest
sol$OFvalue  ### should be zero (with luck)

## a vectorised Rosenbrock function: works only with a *matrix* x
OF2 <- function(x) {
  n <- dim(x)[1L]
  xi <- x[seq_len(n - 1L), ]
  colSums(100 * (x[2L:n, ] - xi * xi)^2 + (1 - xi)^2)
}

## random solutions (every column of 'x' is one solution)
x <- matrix(rnorm(size * algo$nP), size, algo$nP)
all.equal(OF2(x)[1:3],  
          c(OF(x[,1L]), OF(x[,2L]), OF(x[,3L])))

## run DEopt and compare computing time
algo$loopOF <- FALSE
(t2 <- system.time(sol2 <- DEopt(OF = OF2, algo = algo)))
sol2$xbest
sol2$OFvalue  ### should be zero (with luck)
t1[3L]/t2[3L]  ### speedup

divRatio  

### Diversification Ratio

divRatio  

Description

Compute the diversification ratio of a portfolio.

Usage

divRatio(w, var)

Arguments

w  numeric: a vector of weights
var  numeric matrix: the variance–covariance matrix
**Details**

The function provides an efficient implementation of the diversification ratio, suitable for optimisation.

**Value**

a numeric vector of length one

**Author(s)**

Enrico Schumann

**References**


**See Also**

pm, drawdown

**Examples**

```r
na <- 10  # number of assets
rho <- 0.5  # correlation
v_min <- 0.2  # minimum vol
v_max <- 0.4  # maximum vol

# set up a covariance matrix S
C <- array(rho, dim = c(na, na))
diag(C) <- 1
vols <- seq(v_min, v_max, length.out = na)
S <- outer(vols, vols) * C

w <- rep(1/na, na)  # weights
divRatio(w, S)
```

---

**Description**

Compute the drawdown of a time series.
drawdown

Usage

drawdown(v, relative = TRUE, summary = TRUE)

Arguments

- `v`: a price series (a numeric vector)
- `relative`: if TRUE, maximum drawdown is chosen according to percentage losses; else in units of `v`
- `summary`: if TRUE, provide maximum drawdown and time when it occurred; else return drawdown vector

Details

The drawdown at position `t` of a time series `v` is the difference between the highest peak that was reached before `t` and the current value. If the current value represents a new high, the drawdown is zero.

Value

- If `summary` is FALSE, a vector of the same length as `v`. If `summary` is TRUE, a list containing:
  - `maximum`: maximum drawdown
  - `high`: the max of `v`
  - `high.position`: position of `high`
  - `low`: the min of `v`
  - `low.position`: position of `low`

Author(s)

Enrico Schumann

References


See Also
drawdowns

Examples

```r
v <- cumprod(1 + rnorm(20) * 0.02)
drawdown(v)
```
**Description**

Computes the fair value of a European Call with the binomial tree of Cox, Ross and Rubinstein.

**Usage**

```r
EuropeanCall(S0, X, r, tau, sigma, M = 101)
EuropeanCallBE(S0, X, r, tau, sigma, M = 101)
```

**Arguments**

- `S0`: current stock price
- `X`: strike price
- `r`: risk-free rate
- `tau`: time to maturity
- `sigma`: volatility
- `M`: number of time steps

**Details**

Prices a European Call with the tree approach of Cox, Ross, Rubinstein.

The algorithm in `EuropeanCallBE` does not construct and traverse a tree, but computes the terminal prices via a binomial expansion (see Higham, 2002, and Chapter 5 in Gilli/Maringer/Schumann, 2011).

**Value**

Returns the value of the call (numeric).

**Author(s)**

Enrico Schumann

**References**


See Also

callHestoncf

Examples

## price
EuropeanCall( S0 = 100, X = 100, r = 0.02, tau = 1, sigma = 0.20, M = 50)
EuropeanCallBE(S0 = 100, X = 100, r = 0.02, tau = 1, sigma = 0.20, M = 50)

## a Greek: delta
h <- 1e-8
C1 <- EuropeanCall(S0 = 100 + h, X = 100, r = 0.02, tau = 1,
sigma = 0.20, M = 50)
C2 <- EuropeanCall(S0 = 100, X = 100, r = 0.02, tau = 1,
sigma = 0.20, M = 50)
(C1 - C2) / h

---

French

Download Datasets from Kenneth French’s Data Library

Description

Download datasets from Kenneth French’s Data Library.

Usage

French(dest.dir, 
dataset = "F-F_Research_Data_Factors_CSV.zip", 
weighting = "value", frequency = "monthly", 
price.series = FALSE, na.rm = FALSE, 
adjust.frequency = TRUE)

Arguments

dest.dir character: a path to a directory
dataset a character string: the CSV file name. Also supported are the keywords ‘market’ and ‘rf’.
weighting a character string: "equal" or "value"
frequency a character string: daily, monthly or annual. Whether it is used or ignored depends on the particular dataset.
price.series logical: convert the returns series into prices series?
na.rm logical: remove missing values in the calculation of price series?
adjust.frequency logical: if TRUE, frequency is switched to “daily” when the word “daily” appears in the dataset’s name
Details

The function downloads data provided by Kenneth French at http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html. The download file gets a date prefix (current date in format YYYYMMDD) and is stored in directory dest.dir. Before any download is attempted, the function checks whether a file with today’s prefix exist in dest.dir; if yes, the file is used.

In the original data files, missing values are coded as -99 or similar. These numeric values are replaced by NA.

Calling the function without any arguments will print the names of the supported datasets (and return them invisibly).

Value

a data.frame, with contents depending on the particular dataset

Author(s)

Enrico Schumann

References


See Also

Shiller

Examples

```r
## list all supported files
French()

## Not run:
archive.dir <- "~/Downloads/French"
if (!dir.exists(archive.dir))
  dir.create(archive.dir)
French(archive.dir, "F-F_Research_Data_Factors_CSV.zip")

## End(Not run)
```
fundData

**Description**

A matrix of 500 rows (return scenarios) and 200 columns (mutual funds). The elements in the matrix are weekly returns.

**Usage**

fundData

**Format**

A plain numeric matrix.

**Details**

The scenarios were created with a bootstrapping technique. The data set is only meant to provide example data on which to test algorithms.

**Source**


**References**


**Examples**

```r
apply(fundData, 2, summary)
```
GAopt

Optimisation with a Genetic Algorithm

Description

A simple Genetic Algorithm for minimising a function.

Usage

GAopt (OF, algo = list(), ...)

Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OF</td>
<td>The objective function, to be minimised. See Details.</td>
</tr>
<tr>
<td>algo</td>
<td>A list with the settings for algorithm. See Details and Examples.</td>
</tr>
<tr>
<td>...</td>
<td>Other pieces of data required to evaluate the objective function. See Details and Examples.</td>
</tr>
</tbody>
</table>

Details

The function implements a simple Genetic Algorithm (GA). A GA evolves a collection of solutions (the so-called population), all of which are coded as vectors containing only zeros and ones. (In GAopt, solutions are of mode logical.) The algorithm starts with randomly-chosen or user-supplied population and aims to iteratively improve this population by mixing solutions and by switching single bits in solutions, both at random. In each iteration, such randomly-changed solutions are compared with the original population and better solutions replace inferior ones. In GAopt, the population size is kept constant.

GA language: iterations are called generations; new solutions are called offspring or children (and the existing solutions, from which the children are created, are parents); the objective function is called a fitness function; mixing solutions is a crossover; and randomly changing solutions is called mutation. The choice which solutions remain in the population and which ones are discarded is called selection. In GAopt, selection is pairwise: a given child is compared with a given parent; the better of the two is kept. In this way, the best solution is automatically retained in the population.

To allow for constraints, the evaluation works as follows: after new solutions are created, they are (i) repaired, (ii) evaluated through the objective function, (iii) penalised. Step (ii) is done by a call to OF; steps (i) and (iii) by calls to algo$repair and algo$pen. Step (i) and (iii) are optional, so the respective functions default to NULL. A penalty can also be directly written in the OF, since it amounts to a positive number added to the ‘clean’ objective function value; but a separate function is often clearer. A separate penalty function is advantageous if either only the objective function or only the penalty function can be vectorised.

Conceptually a GA consists of two loops: one loop across the generations and, in any given generation, one loop across the solutions. This is the default, controlled by the variables algo$loopOF, algo$loopRepair and algo$loopPen, which all default to TRUE. But it does not matter in what order the solutions are evaluated (or repaired or penalised), so the second loop can be vectorised. The respective algo$loopFun must then be set to FALSE. (See also the examples for DEopt and PSopt.)
The evaluation of the objective function in a given generation can even be distributed. For this, an argument \texttt{algo$methodOF} needs to be set; see below for details (and Schumann, 2011, for examples).

All objects that are passed through \ldots will be passed to the objective function, to the repair function and to the penalty function.

The list \texttt{algo} contains the following items:

- \texttt{nB} number of bits per solution. Must be specified.
- \texttt{nP} population size. Defaults to 50. Using default settings may not be a good idea.
- \texttt{nG} number of iterations ('generations'). Defaults to 300. Using default settings may not be a good idea.
- \texttt{crossover} The crossover method. Default is "onePoint"; also possible is "uniform".
- \texttt{prob} The probability for switching a single bit. Defaults to 0.01; typically a small number.
- \texttt{pen} a penalty function. Default is \texttt{NULL} (no penalty).
- \texttt{repair} a repair function. Default is \texttt{NULL} (no repairing).
- \texttt{initP} optional: the initial population. A logical matrix of size \texttt{length(algo$nB) times algo$nP}, or a function that creates such a matrix. If a function, it must take no arguments. If \texttt{mode(mP)} is not logical, then \texttt{storage.mode(mP)} will be tried (and a warning will be issued).
- \texttt{loopOF} logical. Should the \texttt{OF} be evaluated through a loop? Defaults to \texttt{TRUE}.
- \texttt{loopPen} logical. Should the penalty function (if specified) be evaluated through a loop? Defaults to \texttt{TRUE}.
- \texttt{loopRepair} logical. Should the repair function (if specified) be evaluated through a loop? Defaults to \texttt{TRUE}.
- \texttt{methodOF} loop (the default), vectorised, snow or multicore. Setting \texttt{vectorised} is equivalent to having \texttt{algo$loopOF set to FALSE} (and \texttt{methodOF overrides loopOF}). \texttt{snow} and \texttt{multicore} use functions \texttt{clusterApply} and \texttt{mclapply}, respectively. For \texttt{snow}, an object \texttt{algo$cl} needs to be specified (see below). For \texttt{multicore}, optional arguments can be passed through \texttt{algo$mc.control} (see below).
- \texttt{cl} a cluster object or the number of cores. See documentation of package \texttt{parallel}.
- \texttt{mc.control} a list of named elements; optional settings for \texttt{mclapply} (for instance, \texttt{list(mc.set.seed = FALSE)}).
- \texttt{printDetail} If \texttt{TRUE} (the default), information is printed.
- \texttt{printBar} If \texttt{TRUE} (the default), a \texttt{txtProgressBar} is printed.
- \texttt{storeF} If \texttt{TRUE} (the default), the objective function values for every solution in every generation are stored and returned as matrix \texttt{Fmat}.
- \texttt{storeSolutions} If \texttt{TRUE}, the solutions (ie, binary strings) in every generation are stored and returned as a list \texttt{P} in list \texttt{xlist} (see Value section below). To check, for instance, the solutions at the end of the \texttt{i}th generation, retrieve \texttt{xlist[[c(1L,i)]]}. This will be a matrix of size \texttt{algo$nB times algo$nP}.
- \texttt{classify} Logical; default is \texttt{FALSE}. If \texttt{TRUE}, the result will have a class attribute \texttt{TAopt} attached. This feature is \texttt{experimental}: the supported methods may change without warning.
Value

A list:

- `xbest` the solution (the best member of the population)
- `OFvalue` objective function value of best solution
- `popF` a vector. The objective function values in the final population.
- `Fmat` if `algo$storeF` is TRUE, a matrix of size `algo$nG` times `algo$nP` containing the objective function values of all solutions over the generations; else NA
- `xlist` if `algo$storeSolutions` is TRUE, a list that contains a list `P` of matrices and a matrix `initP` (the initial solution); else NA.
- `initial.state` the value of `.Random.seed` when the function was called.

Author(s)

Enrico Schumann

References


See Also

DEopt, PSopt

Examples

```r
## a *very* simple problem (why?):
## match a binary (logical) string y

size <- 20L ### the length of the string
OF <- function(x, y) sum(x != y)
y <- runif(size) > 0.5
x <- runif(size) > 0.5
OF(y, y) ### the optimum value is zero
OF(x, y)
algo <- list(nB = size, nP = 20L, nG = 100L, prob = 0.002)
sol <- GAopt(OF, algo = algo, y = y)

## show differences (if any: marked by a '^

cat(as.integer(y), "\n", as.integer(sol$xbest), "\n", ifelse(y == sol$xbest , " ", "^"), "\n", sep = "")

algo$nP <- 3L ### that shouldn't work so well
sol2 <- GAopt(OF, algo = algo, y = y)
```
greedySearch

Description

Greedy Search

Usage

greedySearch(OF, algo, ...)

Arguments

- **OF**: The objective function, to be minimised. Its first argument needs to be a solution; ... arguments are also passed.
- **algo**: List of settings. See Details.
- **...**: Other variables to be passed to the objective function and to the neighbourhood function. See Details.

Details

A greedy search works starts at a provided initial solution (called the current solution) and searches a defined neighbourhood for the best possible solution. If this best neighbour is not better than the current solution, the search stops. Otherwise, the best neighbour becomes the current solution, and the search is repeated.

Value

A list:

- **xbest**: best solution found.
- **OFvalue**: objective function value associated with best solution.
- **Fmat**: a matrix with two columns. Fmat[,1L] contains the proposed solution over all iterations; Fmat[,2L] contains the accepted solutions.
- **xlist**: a list
- **initial.state**: the value of .Random.seed when the function was called.
- **x0**: the initial solution
- **iterations**: the number of iterations after which the search stopped

Author(s)

Enrico Schumann
greedySearch

References


See Also

LSopt

Examples

na <- 100
inc <- 5
R <- randomReturns(na = na,
   ns = 1000,
   sd = seq(0.01, 0.02, length.out = 100),
   rho = 0.5)
S <- cov(R)
OF <- function(x, S, ...) {
  w <- 1/sum(x)
  sum(w * w * S[x, x])
}
x <- logical(na)
x[1:inc] <- TRUE

all.neighbours <- function(x, ...) {
  true <- which(x)
  false <- which(!x)
  ans <- list()
  for (i in true) {
    for (j in false) {
      ans1 <- x
      ans1[i] <- !x[i]
      ans1[j] <- !x[j]
      ans <- c(ans, list(ans1))
    }
  }
  ans
}
algo <- list(loopOF = TRUE,
               maxit = 1000,
               all.neighbours = all.neighbours,
               x0 = x)

system.time(sol.gs <- greedySearch(OF, algo = algo, S = S))
sqrt(sol.gs$OFvalue)
gridSearch

Grid Search

Description

Evaluate a function for a given list of arguments.

Usage

gridSearch(fun, levels, ..., lower, upper, npar = 1L, n = 5L,
           printDetail = TRUE,
           method = NULL,
           mc.control = list(), cl = NULL,
           keepNames = FALSE, asList = FALSE)

Arguments

fun a function of the form `fun(x,...)`, with `x` being a numeric vector or a list
levels a list of levels for the arguments (see Examples)
... objects passed to `fun`
lower a numeric vector. Ignored if levels are explicitly specified.
upper a numeric vector. Ignored if levels are explicitly specified.
npar the number of parameters. Must be supplied if `lower` and `upper` are to be expanded; see Details. Ignored when levels are explicitly specified, or when `lower/upper` are used and at least one has length greater than one. See Examples.
n the number of levels. Default is 5. Ignored if levels are explicitly specified.
printDetail print information on the number of objective function evaluations
method can be `loop` (the default), `multicore` or `snow`. See Details.
mc.control a list containing settings that will be passed to `mclapply` if `method` is `multicore`. Must be a list of named elements; see the documentation of `mclapply` in `parallel`.
cl default is NULL. If method `snow` is used, this must be a cluster object or an integer (the number of cores).
keepNames logical: should the names of `levels` be kept?
asList does `fun` expect a list? Default is FALSE.
Details

A grid search can be used to find ‘good’ parameter values for a function. In principle, a grid search has an obvious deficiency: as the length of \( x \) (the first argument to \( \text{fun} \)) increases, the number of necessary function evaluations grows exponentially. Note that \( \text{gridSearch} \) will not warn about an unreasonable number of function evaluations, but if \( \text{printDetail} \) is \( \text{TRUE} \) it will print the required number of function evaluations.

In practice, grid search is often better than its reputation. If a function takes only a few parameters, it is often a reasonable approach to find ‘good’ parameter values.

The function uses the mechanism of \( \text{expand.grid} \) to create the list of parameter combinations for which \( \text{fun} \) is evaluated; it calls \( \text{lapply} \) to evaluate \( \text{fun} \) if \( \text{method} == \text{"loop"} \) (the default).

If \( \text{method} \) is \( \text{multicore} \), then function \( \text{mclapply} \) from package \( \text{parallel} \) is used. Further settings for \( \text{mclapply} \) can be passed through the list \( \text{mc.control} \). If \( \text{multicore} \) is chosen but the functionality is not available, then \( \text{method} \) will be set to \( \text{loop} \) and a warning is issued. If \( \text{method} == \text{"snow"} \), the function \( \text{clusterApply} \) from package \( \text{parallel} \) is used. In this case, the argument \( \text{cl} \) must either be a cluster object (see the documentation of \( \text{clusterApply} \)) or an integer. If an integer, a cluster will be set up via \( \text{makeCluster(c(rep("localhost",cl)),type = "SOCK")} \) (and \( \text{stopCluster} \) is called when the function is exited). If \( \text{snow} \) is chosen but not available or \( \text{cl} \) is not specified, then \( \text{method} \) will be set to \( \text{loop} \) and a warning is issued.

Value

A list.

- \( \text{minfun} \) the minimum of \( \text{fun} \).
- \( \text{minlevels} \) the levels that give this minimum.
- \( \text{values} \) a list. All the function values of \( \text{fun} \).
- \( \text{levels} \) a list. All the levels for which \( \text{fun} \) was evaluated.

Author(s)

Enrico Schumann

References


Examples

testFun <- function(x) 
    x[1L] + x[2L]^2

sol <- gridSearch(fun = testFun, levels = list(1:2, c(2, 3, 5)))
sol$minfun
sol$minlevels

## specify all levels
levels <- list(a = 1:2, b = 1:3)
res <- gridSearch(testFun, levels)
res$minfun
sol$minlevels

## specify lower, upper and npar
lower <- 1; upper <- 3; npar <- 2
res <- gridSearch(testFun, lower = lower, upper = upper, npar = npar)
res$minfun
sol$minlevels

## specify lower, upper, npar and n
lower <- 1; upper <- 3; npar <- 2; n <- 4
res <- gridSearch(testFun, lower = lower, upper = upper, npar = npar, n = n)
res$minfun
sol$minlevels

## specify lower, upper and n
lower <- c(1,1); upper <- c(3,3); n <- 4
res <- gridSearch(testFun, lower = lower, upper = upper, n = n)
res$minfun
sol$minlevels

## specify lower, upper (auto-expanded) and n
lower <- c(1,1); upper <- 3; n <- 4
res <- gridSearch(testFun, lower = lower, upper = upper, n = n)
res$minfun
sol$minlevels

## non-numeric inputs

```r
test_fun <- function(x) {
  -(length(x$S) + x$N1 + x$N2)
}
```

ans <- gridSearch(test_fun,
  levels = list(S = list("a", c("a", "b"), c("a", "b", "c")),
                N1 = 1:5,
                N2 = 101:105),
  asList = TRUE, keepNames = TRUE)

ans$minlevels

## $S
## [1] "a" "b" "c"

## $N1
## [1] 5

## $N2
## [1] 105
**LS.info**

*Local-Search Information*

**Description**

The function can be called from the objective and neighbourhood function during a run of **LSopt**; it provides information such as the current iteration.

**Usage**

```
LS.info(n = 0L)
```

**Arguments**

- `n` generational offset; see Details.

**Details**

This function is still experimental.

The function can be called in the neighbourhood function or the objective function during a run of **LSopt**. It evaluates to a list with the state of the optimisation run, such as the current iteration. **LS.info** relies on `parent.frame` to retrieve its information. If the function is called within another function in the neighbourhood or objective function, the argument `n` needs to be increased.

**Value**

A list

- `iteration` current iteration
- `step` same as ‘iteration’

**Author(s)**

Enrico Schumann

**References**


**See Also**

**LSopt, TA.info**
Examples

```r
## MINIMAL EXAMPLE for LSopt

## objective function evaluates to a constant
fun <- function(x)
  0

## neighbourhood function does not even change the solution,
## but it reports information
nb <- function(x) {
  tmp <- LS.info()
  cat("current iteration ", tmp$iteration, "\n")
  x
}

## run LS
algo <- list(nS = 5,
             x0 = rep(0, 5),
             neighbour = nb,
             printBar = FALSE)
ignore <- LSopt(fun, algo)
```

---

### LSopt

**Stochastic Local Search**

**Description**

Performs a simple stochastic Local Search.

**Usage**

`LSopt(OF, algo = list(), ...)`

**Arguments**

- **OF**
  The objective function, to be minimised. Its first argument needs to be a solution; ... arguments are also passed.

- **algo**
  List of settings. See Details.

- **...**
  Other variables to be passed to the objective function and to the neighbourhood function. See Details.

**Details**

Local Search (LS) changes an initial solution for a number of times, accepting only such changes that lead to an improvement in solution quality (as measured by the objective function `OF`). More specifically, in each iteration, a current solution `xc` is changed through a function `algo$neighbour`.
This function takes \( xc \) as an argument and returns a new solution \( xn \). If \( xn \) is not worse than \( xc \), ie, if \( OF(xn,\ldots) \leq OF(xc,\ldots) \), then \( xn \) replaces \( xc \).

The list \( algo \) contains the following items:

- \( nS \): The number of steps. The default is 1000; but this setting depends very much on the problem.
- \( nI \): Total number of iterations, with default \( NULL \). If specified, it will override \( nS \). The option is provided to make it easier to compare and switch between functions \( LSopt \), \( TAopt \) and \( SAopt \).
- \( x0 \): The initial solution. This can be a function; it will then be called once without arguments to compute an initial solution, ie, \( x0 <- algo$x0() \). This can be useful when \( LSopt \) is called in a loop of restarts and each restart is to have its own starting value.
- \( neighbour \): The neighbourhood function, called as \( neighbour(x,\ldots) \). Its first argument must be a solution \( x \); it must return a changed solution.
- \( printDetail \): If \( TRUE \) (the default), information is printed. If an integer \( i \) greater than one, information is printed at every \( i \)th step.
- \( printBar \): If \( TRUE \) (the default), a \( txtProgressBar \) (from package \( utils \)) is printed. The progress bar is not shown if \( printDetail \) is an integer greater than 1.
- \( storeF \): If \( TRUE \) (the default), the objective function values for every solution in every generation are stored and returned as matrix \( Fmat \).
- \( storeSolutions \): default is \( FALSE \). If \( TRUE \), the solutions (ie, decision variables) in every generation are stored and returned in list \( xlist \) (see Value section below). To check, for instance, the current solution at the end of the \( i \)th generation, retrieve \( xlist[[c(2L,i)]] \).
- \( OF.target \): Numeric; when specified, the algorithm will stop when an objective-function value as low as \( OF.target \) (or lower) is achieved. This is useful when an optimal objective-function value is known: the algorithm will then stop and not waste time searching for a better solution.

At the minimum, \( algo \) needs to contain an initial solution \( x0 \) and a \( neighbour \) function.

\( LS \) works on solutions through the functions \( neighbour \) and \( OF \), which are specified by the user. Thus, a solution need not be a numeric vector, but can be any other data structure as well (eg, a list or a matrix).

To run silently (except for warnings and errors), \( algo\$printDetail \) and \( algo\$printBar \) must be \( FALSE \).

**Value**

A list:

- \( xbest \): best solution found.
- \( OFvalue \): objective function value associated with best solution.
- \( Fmat \): a matrix with two columns. \( Fmat[,1L] \) contains the proposed solution over all iterations; \( Fmat[,2L] \) contains the accepted solutions.
- \( xlist \): if \( algo\$storeSolutions \) is \( TRUE \), a list; else \( NA \). Contains the neighbour solutions at a given iteration (\( xn \)) and the current solutions (\( xc \)). Example: \( Fmat[i,2L] \) is the objective function value associated with \( xlist[[c(2L,i)]] \).
- \( initial.state \): the value of \( .Random.seed \) when the function was called.
Author(s)

Enrico Schumann

References


See Also

TAopt, restartOpt

Examples

## Aim: find the columns of X that, when summed, give y

## random data set
nc <- 25L  # number of columns in data set
r <- 5L   # number of rows in data set
howManyCols <- 5L  # length of true solution
X <- array(runif(nr*nc), dim = c(nr, nc))
xTRUE <- sample(1L:nc, howManyCols)
Xt <- X[, xTRUE, drop = FALSE]
y <- rowSums(Xt)

## a random solution x0 ...
makeRandomSol <- function(nc) {
  ii <- sample.int(nc, sample.int(nc, 1L))
x0 <- logical(nc); x0[ii] <- TRUE
x0
}
x0 <- makeRandomSol(nc)

## ... but probably not a good one
sum(y - rowSums(X[, xTRUE, drop = FALSE]))  # should be 0
sum(y - rowSums(X[, x0, drop = FALSE]))

## a neighbourhood function: switch n elements in solution
neighbour <- function(xc, Data) {
  xn <- xc
  p <- sample.int(Data$nc, Data$n)
xn[p] <- !xn[p]
  if (sum(xn) < 1L)
    xn <- xc
  xn
}

## a greedy neighbourhood function
neighbourG <- function(xc, Data) {
  of <- function(x)
    abs(sum(Data$y - rowSums(Data$X[, x, drop = FALSE])))
  xbest <- xc
  Fxbest <- of(xbest)
  for (i in 1L:Data$nc) {
    xn <- xc; p <- i
    xn[p] <- !xn[p]
    if (sum(xn) >= 1L) {
      Fxn <- of(xn)
      if (Fxn < Fxbest) {
        xbest <- xn
        Fxbest <- Fxn
      }
    }
  }
  xbest
}

## an objective function
OF <- function(xn, Data)
  abs(sum(Data$y - rowSums(Data$X[, xn, drop = FALSE])))

## (1) GREEDY SEARCH
## note: this could be done in a simpler fashion, but the
## redundancies/overhead here are small, and the example is to
## show how LSopt can be used for such a search
Data <- list(X = X, y = y, nc = nc, nr = nr, n = 1L)
algo <- list(nS = 500L, neighbour = neighbourG, x0 = x0,
  printBar = FALSE, printDetail = FALSE)
solG <- LSopt(OF, algo = algo, Data = Data)

## after how many iterations did we stop?
iterG <- min(which(solG$Fmat[, 2L] == solG$OFvalue))
solG$OFvalue ## the true solution has OF-value 0

## (2) LOCAL SEARCH
algo$neighbour <- neighbour
solLS <- LSopt(OF, algo = algo, Data = Data)
iterLS <- min(which(solLS$Fmat[, 2L] == solLS$OFvalue))
solLS$OFvalue ## the true solution has OF-value 0

## (3) *Threshold Accepting*
algo$nT <- 10L
algo$nS <- ceiling(algo$nS/algo$nT)
algo$q <- 0.99
solTA <- TAopt(OF, algo = algo, Data = Data)
iterTA <- min(which(solTA$Fmat[, 2L] == solTA$OFvalue))
solTA$OFvalue ## the true solution has OF-value 0

## look at the solution
all <- sort(unique(c(which(solTA$xbest),

LSopt
which(solLS$xbest),
which(solG$xbest),
xTRUE))}

```r
ta <- ls <- greedy <- true <- character(length(all))
true[ match(xTRUE, all)] <- "o"
greedy[match(which(solG$xbest), all)] <- "o"
ls[ match(which(solLS$xbest), all)] <- "o"
ta[ match(which(solTA$xbest), all)] <- "o"
data.frame(true = true, greedy = greedy, LS = ls, TA = ta,
row.names=all)
```

```r
## plot results
par(ylog = TRUE, mar = c(5,5,1,6), las = 1)
plot(solTA$Fmat[seq_len(iterTA) ,2L],type = "l", log = "y",
ylim = c(1e-4,
    max(pretty(c(solG$Fmat,solLS$Fmat,solTA$Fmat)))))
xlab = "iterations", ylab = "OF value", col = grey(0.5))
lines(cummin(solTA$Fmat[seq_len(iterTA), 2L]), type = "l")
lines(solG$Fmat[ seq_len(iterG), 2L], type = "p", col = "blue")
lines(solLS$Fmat[seq_len(iterLS), 2L], type = "l", col = "goldenrod3")
legend(x = "bottomleft",
        legend = c("TA best solution", "TA current solution",
                  "Greedy", "LS current/best solution"),
lty = c(1,1,0,1),
col = c("black",grey(0.5),"blue","goldenrod2"),
pch = c(NA,NA,21,NA))
axis(4, at = c(solG$OFvalue, solLS$OFvalue, solTA$OFvalue),
      labels = NULL, las = 1)
lines(x = c(iterG, par()$usr[2L]), y = rep(solG$OFvalue,2),
col = "blue", lty = 3)
lines(x = c(iterTA, par()$usr[2L]), y = rep(solTA$OFvalue,2),
col = "black", lty = 3)
lines(x = c(iterLS, par()$usr[2L]), y = rep(solLS$OFvalue,2),
col = "goldenrod3", lty = 3)
```

**MA**

*Simple Moving Average*

**Description**

The function computes a moving average of a vector.

**Usage**

```r
MA(y, order, pad = NULL)
```

**Arguments**

- **y**: a numeric vector
order  An integer. The order of the moving average. The function is defined such that order one returns \( y \) (see Examples).

pad  Defaults to NULL. If not NULL, all elements of the returned moving average with position smaller than order are replaced by the value of pad. Sensible values may be NA or 0.

Value

Returns a vector of length \( \text{length}(y) \).

Author(s)

Enrico Schumann

References


Examples

```r
MA(1:10, 3)
MA(1:10, 3, pad = NA)

y <- seq(1, 4, by = 0.3)
z <- MA(y, 1)
all(y == z)  ### (typically) FALSE
all.equal(y, z)  ### should be TRUE

## 'Relative strength index'
rsi <- function(y, t) {
  y <- diff(y)
  ups <- y + abs(y)
  downs <- y - abs(y)
  RS <- -MA(ups, t) / MA(downs, t)
  RS/(1 + RS)
}
x <- cumprod(c(100, 1 + rnorm(100, sd = 0.01)))
par(mfrow = c(2,1))
plot(x, type = "l")
plot(rsi(x, 14), ylim = c(0,1), type = "l")
```
Description

Functions to calculate the theoretical prices of options through simulation.

Usage

```r
gbm(npaths, timesteps, r, v, tau, S0)
gbb(npaths, timesteps, S0, ST, v, tau)
```

Arguments

- `npaths`: the number of paths
- `timesteps`: timesteps per path
- `r`: the mean per unit of time
- `v`: the variance per unit of time
- `tau`: time
- `S0`: initial value
- `ST`: final value of Brownian bridge

Details

- `gbm` generates sample paths of geometric Brownian motion.
- `gbb` generates sample paths of a Brownian bridge by first creating paths of Brownian motion \( \mathbb{W} \) from time 0 to time \( T \), with \( \mathbb{W}_0 = 0 \). Then, at each \( t \), it subtracts \( t/T \times \mathbb{W}_T \) and adds \( S0*(1-t/T)+ST*(t/T) \).

Value

A matrix of sample paths; each column contains the price path of an asset. Even with only a single time-step, the matrix will have two rows (the first row is \( S0 \)).

Author(s)

Enrico Schumann

References


mc

See Also

vanillaOptionEuropean

Examples

```r
## price a European option
## ... parameters
npaths <- 5000  ## increase number to get more precise results
timesteps <- 1
S0  <- 100
ST  <- 100
tau <- 1
r   <- 0.01
v   <- 0.25^2

## ... create paths
paths <- gbm(npaths, timesteps, r, v, tau, S0 = S0)

## ... a helper function
mc <- function(paths, payoff, ...) 
  payoff(paths, ...)

## ... a payoff function (European call)
payoff <- function(paths, X, r, tau)
  exp(-r * tau) * mean(pmax(paths[NROW(paths), ] - X, 0))

## ... compute and check
mc(paths, payoff, X = 100, r = r, tau = tau)
vanillaOptionEuropean(S0, X = 100, tau = tau, r = r, v = v)$value

## compute delta via forward difference
## (see Gilli/Maringer/Schumann, ch. 9)
h <- 1e-6  ## a small number
rnorm(1)  ## make sure RNG is initialised
rnd.seed <- .Random.seed  ## store current seed
paths1 <- gbm(npaths, timesteps, r, v, tau, S0 = S0)
.Random.seed <- rnd.seed
paths2 <- gbm(npaths, timesteps, r, v, tau, S0 = S0 + h)

delta.mc <- (mc(paths2, payoff, X = 100, r = r, tau = tau) - 
  mc(paths1, payoff, X = 100, r = r, tau = tau))/h
delta <- vanillaOptionEuropean(S0, X = 100, tau = tau, 
  r = r, v = v)$delta
delta.mc - delta

## a fanplot
steps <- 100
paths <- results <- gbm(1000, steps, r = 0, v = 0.2^2,
```

levels <- seq(0.01, 0.49, length.out = 20)
greys <- seq(0.9, 0.50, length.out = length(levels))

## start with an empty plot ...
plot(0:steps, rep(100, steps+1), ylim = range(paths),
     xlab = "", ylab = "", lty = 0, type = "l")

## ... and add polygons
for (level in levels) {
  l <- apply(paths, 1, quantile, level)
  u <- apply(paths, 1, quantile, 1 - level)
  col <- grey(greys[level == levels])
  polygon(c(0:steps, steps:0), c(l, rev(u)),
          col = col, border = NA)

  ## add border lines
  ## lines(0:steps, l, col = grey(0.4))
  ## lines(0:steps, u, col = grey(0.4))
}

### minCVaR

**Minimum Conditional-Value-at-Risk (CVaR) Portfolios**

**Description**

Compute minimum-CVaR portfolios, subject to lower and upper bounds on weights.

**Usage**

```r
minCVaR(R, q = 0.1, wmin = 0, wmax = 1,
        min.return = NULL, m = NULL,
        method = "Rglpk",
        groups = NULL, groups.wmin = NULL, groups.wmax = NULL,
        Rglpk.control = list())
```

**Arguments**

- **R**
  - the scenario matrix: a numeric (real) matrix
- **q**
  - the Value-at-Risk level: a number between 0 and 0.5
- **wmin**
  - numeric: a lower bound on weights. May also be a vector that holds specific bounds for each asset.
- **wmax**
  - numeric: an upper bound on weights. May also be a vector that holds specific bounds for each asset.
- **m**
  - vector of expected returns. Only used if `min.return` is specified.
minCVaR

min.return  minimal required return. If \( m \) is not specified, the column means of \( R \) are used.
method      character. Currently, only "\texttt{Rglpk}" is supported.
groups      a list of group definitions
groups.wmin a numeric vector
groups.wmax a numeric vector
Rglpk.control a list: settings passed to \texttt{Rglpk\_solve\_LP}

Details

Compute the minimum CVaR portfolio for a given scenario set. The default method uses the formulation as a Linear Programme, as described in Rockafellar/Uryasev (2000).

The function uses \texttt{Rglpk\_solve\_LP} from package \texttt{Rglpk}.

Value

a numeric vector (the portfolio weights); attached is an attribute whose name matches the method name

Author(s)

Enrico Schumann

References


See Also

\texttt{minvar}

Examples

```r
if (requireNamespace("Rglpk")) {
  ns <- 5000  ## number of scenarios
  na <- 20    ## number of assets
  R <- randomReturns(na, ns, sd = 0.01, rho = 0.5)

  res <- minCVaR(R, 0.25)
  c(res)  ## portfolio weights
}
```
Minimum-Variance Portfolios

Description

Compute minimum-variance portfolios, subject to lower and upper bounds on weights.

Usage

```r
minvar(var, wmin = 0, wmax = 1, method = "qp",
       groups = NULL, groups.wmin = NULL, groups.wmax = NULL)
```

Arguments

- `var` the covariance matrix: a numeric (real), symmetric matrix
- `wmin` numeric: a lower bound on weights. May also be a vector that holds specific bounds for each asset.
- `wmax` numeric: an upper bound on weights. May also be a vector that holds specific bounds for each asset.
- `method` character. Currently, only "qp" is supported.
- `groups` a list of group definitions
- `groups.wmin` a numeric vector
- `groups.wmax` a numeric vector

Details

The function uses `solve.QP` from package `quadprog`. Because of the algorithm that `solve.QP` uses, `var` has to be positive definit (i.e. must be of full rank).

Value

a numeric vector (the portfolio weights) with an attribute `variance` (the portfolio’s variance)

Author(s)

Enrico Schumann

References


**minvar**

See Also

TAopt

Examples

```r
## variance-covariance matrix from daily returns, 1 Jan 2014 -- 31 Dec 2013, of
## cleaned data set at http://enricoschumann.net/data/gilli_accuracy.html

if (requireNamespace("quadprog")) {
  var <- structure(c(0.000988087100677907, -0.0000179669410403153, 0.000368923882626859,
                     0.000208303611101873, 0.000262742052359594, -0.0000179669410403153,
                     0.00171852167358765, 0.0000857467457561209, 0.0000215059246610556,
                     0.0000283532159921211, 0.000368923882626859, 0.0000857467457561209,
                     0.00075871953281751, 0.000194002299424151, 0.000188824454515841,
                     0.000208303611101873, 0.0000857467457561209, 0.000194002299424151,
                     0.000265780633005374, 0.000132611196599808, 0.000267424052359594,
                     0.0000283532159921211, 0.000188824454515841, 0.000132611196599808,
                     0.00025948420130626),
  .Dim = c(5L, 5L),
  .Dimnames = list(c("CBK.DE", "VOW.DE", "CON.DE", "LIN.DE", "MUV2.DE"),
                   c("CBK.DE", "VOW.DE", "CON.DE", "LIN.DE", "MUV2.DE")))

## CBK.DE  VOW.DE  CON.DE  LIN.DE  MUV2.DE
## CBK.DE  0.000988 -0.0000180  0.0003689  0.0002083  0.0002627
## VOW.DE -0.000018  0.0017185  0.0000857  0.0000215  0.0000284
## CON.DE  0.000369  0.0000857  0.0007587  0.0001940  0.0001888
## LIN.DE  0.000208  0.0000215  0.0001940  0.0002658  0.0001326
## MUV2.DE 0.000263  0.0000284  0.0001888  0.0001326  0.0002595

minvar(var, wmin = 0, wmax = 0.5)

minvar(var,
       wmin = c(0.1,0,0,0,0), ## enforce at least 10% weight in CBK.DE
       wmax = 0.5)

minvar(var, wmin = -Inf, wmax = Inf)  ## no bounds
## [1] -0.0467  0.0900  0.0117  0.4534  0.4916

minvar(var, wmin = -Inf, wmax = 0.45)  ## no lower bounds
## [1] -0.0284  0.0977  0.0367  0.4500  0.4500

minvar(var, wmin = 0.1, wmax = Inf)  ## no upper bounds
## [1] 0.100 0.100 0.100 0.363 0.337

## group constraints:
## group 1 consists of asset 1 only, and must have weight [0.25,0.30]
## group 2 consists of assets 4 and 5, and must have weight [0.10,0.20]
## => unconstrained

minvar(var, wmin = 0, wmax = 0.40)
```
mvFrontier

## [1] 0.0097 0.1149 0.0754 0.4000 0.4000

## => with group constraints
minvar(var, wmin = 0, wmax = 0.40,
groups = list(1:4:5),
groups.wmin = c(0.25, 0.1),
groups.wmax = c(0.30, 0.2))
## [1] 0.250 0.217 0.333 0.149 0.051

---

### Description

Compute mean–variance efficient portfolios and efficient frontiers.

### Usage

\[
\text{mvFrontier}(m, \text{var}, \text{wmin} = 0, \text{wmax} = 1, n = 50, \text{rf} = \text{NA}, \\
\text{groups} = \text{NULL}, \text{groups.wmin} = \text{NULL}, \text{groups.wmax} = \text{NULL})
\]

\[
\text{mvPortfolio}(m, \text{var}, \text{min.return}, \text{wmin} = 0, \text{wmax} = 1, \text{lambda} = \text{NULL}, \\
\text{groups} = \text{NULL}, \text{groups.wmin} = \text{NULL}, \text{groups.wmax} = \text{NULL})
\]

### Arguments

- **m**: vector of expected returns
- **var**: expected variance–covariance matrix
- **wmin**: numeric: minimum weights
- **wmax**: numeric: maximum weights
- **n**: number of points on the efficient frontier
- **min.return**: minimal required return
- **rf**: risk-free rate
- **lambda**: risk–reward trade-off
- **groups**: a list of group definitions
- **groups.wmin**: a numeric vector
- **groups.wmax**: a numeric vector

### Details

`mvPortfolio` computes a single mean–variance efficient portfolio, using package `quadprog`. It does so by minimising portfolio variance, subject to constraints on minimum return and budget (weights need to sum to one), and min/max constraints on the weights.
If $\lambda$ is specified, the function ignores the min. return constraint and instead solves the model

$$\min_w -\lambda m' w + (1 - \lambda)w' \text{var} w$$

in which $w$ are the weights. If $\lambda$ is a vector of length 2, then the model becomes

$$\min_w -\lambda_1 m' w + \lambda_2 w' \text{var} w$$

which may be more convenient (e.g. for setting $\lambda_1$ to 1).

`mvFrontier` computes returns, volatilities and compositions for portfolios along an efficient frontier. If rf is not NA, cash is included as an asset.

**Value**

For `mvPortfolio`, a numeric vector of weights.

For `mvFrontier`, a list of three components:

- `return` returns of portfolios
- `volatility` volatilities of portfolios
- `weights` A matrix of portfolio weights. Each column holds the weights for one portfolio on the frontier. If rf is specified, an additional row is added, providing the cash weight.

The $i$-th portfolio on the frontier corresponds to the $i$-th elements of `return` and `volatility`, and the $i$-th column of `portfolio`.

**Author(s)**

Enrico Schumann

**References**


**See Also**

`minvar` for computing the minimum-variance portfolio

**Examples**

```r
na <- 4
vols <- c(0.10, 0.15, 0.20, 0.22)
m <- c(0.06, 0.12, 0.09, 0.07)
const_cor <- function(rho, na) {
  C <- array(rho, dim = c(na, na))
  ...}
```
NS <- diag(C) <- 1
C
}
var <- diag(vols) %*% const_cor(0.5, na) %*% diag(vols)
wmax <- 1       # maximum holding size
wmin <- 0.0     # minimum holding size
rf <- 0.02

p1 <- mvFrontier(m, var, wmin = wmin, wmax = wmax, n = 50)
p2 <- mvFrontier(m, var, wmin = wmin, wmax = wmax, n = 50, rf = rf)
plot(p1$return, p1$volatility, pch = 19, cex = 0.5, type = "o",
xlab = "Expected volatility",
ylab = "Expected return")
lines(p2$return, p2$volatility, pch = 19, cex = 0.5, type = "o",
lines(p2$volatility, p2$return, col = grey(0.5))
abline(v = 0, h = rf)

---

**NS**

*Zero Rates for Nelson–Siegel–Svensson Model*

**Description**


**Usage**

```r
NS(param, tm)
NSS(param, tm)
```

**Arguments**

- `param` a vector. For NS: \( \beta_1, \beta_2, \beta_3, \lambda \). For NSS: a vector: \( \beta_1, \beta_2, \beta_3, \beta_4, \lambda_1, \lambda_2 \).
- `tm` a vector of maturities

**Details**

See Chapter 14 in Gilli/Maringer/Schumann (2011).

Maturities (tm) need to be given in time (not dates).

**Value**

The function returns a vector of length `length(tm)`.

**Author(s)**

Enrico Schumann
References


See Also

NSf, NSSf

Examples

```r
tm <- c(c(1, 3, 6, 9) / 12, 1:10) ## in years
param <- c(6, 3, 8, 1)
yM <- NS(param, tm)
plot(tm, yM, xlab = "maturity in years",
     ylab = "yield in percent")

param <- c(6, 3, 5, -5, 1, 3)
yM <- NSS(param, tm)
plot(tm, yM, xlab = "maturity in years",
     ylab = "yield in percent")
```

## Not run:

## get Bliss/Diebold/Li data (used in some of the papers in References)

```r
u <- url("http://www.ssc.upenn.edu/~fdiebold/papers/paper49/FBFITTED.txt")
open(u); Blidili <- scan(u, skip = 14); close(u)
mat <- NULL
for (i in 1:372)
  mat <- rbind(mat, Blidili[(19*(i-1)+1):(19*(i-1)+19)])
mats <- c(1,3,6,9,12,15,18,21,24,30,36,48,60,72,84,96,108,120)/12
```

## the obligatory perspective plot

```r
persp(x = mat[,1], y = mats, mat[ , -1L],
     phi = 30, theta = 30, ticktype = "detailed",
     xlab = "time",
     ylab = "time to maturity in years",
     zlab = "zero rates in ")
```
## End(Not run)

### NSf

**Factor Loadings for Nelson–Siegel and Nelson–Siegel–Svensson**

**Description**

Computes the factor loadings for Nelson–Siegel (NS) and Nelson–Siegel–Svensson (NSS) model for given lambda values.

**Usage**

```r
NSf(lambda, tm)
NSSf(lambda1, lambda2, tm)
```

**Arguments**

- `lambda` the $\lambda$ parameter of the NS model (a scalar)
- `lambda1` the $\lambda_1$ parameter of the NSS model (a scalar)
- `lambda2` the $\lambda_2$ parameter of the NSS model (a scalar)
- `tm` a numeric vector with times-to-payment/maturity

**Details**

The function computes the factor loadings for given $\lambda$ parameters. Checking the correlation between these factor loadings can help to set reasonable $\lambda$ values for the NS/NSS models.

**Value**

For NS, a matrix with `length(tm)` rows and three columns. For NSS, a matrix with `length(tm)` rows and four columns.

**Author(s)**

Enrico Schumann

**References**


### See Also

NS, NSS

### Examples

```r
## Nelson-Siegel
cor(NSf(lambda = 6, tm = 1:10)[-1L, -1L])
```

```r
## Nelson-Siegel-Svensson
cor(NSSf(lambda1 = 1, lambda2 = 5, tm = 1:10)[-1L, -1L])
cor(NSSf(lambda1 = 4, lambda2 = 9, tm = 1:10)[-1L, -1L])
```

---

### optionData

**Option Data**

**Description**

Closing prices of DAX index options as of 2012-02-10.

**Usage**

```r
optionData
```

**Format**

- `optionData` is a list with six components:
  - `pricesCall` a matrix of size 124 times 10. The rows are the strikes; each column belongs to one expiry date.
  - `pricesPut` a matrix of size 124 times 10
  - `index` The DAX index (spot).
  - `future` The available future settlement prices.
  - `Euribor` Euribor rates.
  - `NSSpar` Parameters for German government bond yields, as estimated by the Bundesbank.

**Details**

Settlement prices for EUREX options are computed at 17:30, Frankfurt Time, even though trading continues until 22:00.
Source

The data was obtained from several websites: close prices of EUREX products were collected from https://www.eurex.com/ex-en/; Euribor rates and the parameters of the Nelson-Siegel-Svensson can be found at https://www.bundesbank.de/en/.

References


Examples

str(optionData)
NSS(optionData$NSSpar, 1:10)

---

pm Partial Moments

Description

Compute partial moments.

Usage

pm(x, xp = 2, threshold = 0, lower = TRUE, normalise = FALSE, na.rm = FALSE)

Arguments

x a numeric vector or a matrix
xp exponent
threshold a numeric vector of length one
lower logical
normalise logical
na.rm logical
Details

For a vector \( x \) of length \( n \), partial moments are computed as follows:

\[
\text{upper partial moment} = \frac{1}{n} \sum_{x > t} (x - t)^e
\]

\[
\text{lower partial moment} = \frac{1}{n} \sum_{x < t} (t - x)^e
\]

The threshold is denoted \( t \), the exponent \( x^p \) is labelled \( e \).

If \( \text{normalise} \) is \( \text{TRUE} \), the result is raised to \( 1/x^p \). If \( x \) is a matrix, the function will compute the partial moments column-wise.

See Gilli, Maringer and Schumann (2011), Section 13.3.

Value

numeric

Author(s)

Enrico Schumann

References


Examples

```r
pm(x <- rnorm(100), 2)
var(x)/2

pm(x, 2, normalise = TRUE)
sqrt(var(x)/2)
```
Description

The function implements Particle Swarm Optimisation.

Usage

\[
\text{PSopt}(\text{OF}, \text{algo} = \text{list()}, \ldots)
\]

Arguments

\[
\begin{align*}
\text{OF} & \quad \text{the objective function to be minimised. See Details.} \\
\text{algo} & \quad \text{a list with the settings for algorithm. See Details and Examples.} \\
\ldots & \quad \text{pieces of data required to evaluate the objective function. See Details.}
\end{align*}
\]

Details

The function implements Particle Swarm Optimisation (PS); see the references for details on the implementation. PS is a population-based optimisation heuristic. It develops several solutions (a ‘population’) over a number of iterations. PS is directly applicable to continuous problems since the population is stored in real-valued vectors. In each iteration, a solution is updated by adding another vector called velocity. Think of a solution as a position in the search space, and of velocity as the direction into which this solution moves. Velocity changes over the course of the optimization: it is biased towards the best solution found by the particular solution and the best overall solution. The algorithm stops after a fixed number of iterations.

To allow for constraints, the evaluation works as follows: after a new solution is created, it is (i) repaired, (ii) evaluated through the objective function, (iii) penalised. Step (ii) is done by a call to \text{OF}; steps (i) and (iii) by calls to \text{algo$\text{repair}$} and \text{algo$\text{pen}$}. Step (i) and (iii) are optional, so the respective functions default to \text{NULL}. A penalty can also be directly written in the \text{OF}, since it amounts to a positive number added to the ‘clean’ objective function value. It can be advantageous to write a separate penalty function if either only the objective function or only the penalty function can be vectorised. (Constraints can also be added without these mechanisms. Solutions that violate constraints can, for instance, be mapped to feasible solutions, but without actually changing them. See Maringer and Oyewumi, 2007, for an example with Differential Evolution.)

Conceptually, PS consists of two loops: one loop across the iterations and, in any given generation, one loop across the solutions. This is the default, controlled by the variables \text{algo$\text{loopOF}$}, \text{algo$\text{loopRepair}$}, \text{algo$\text{loopPen}$} and \text{loopChangeV} which all default to \text{TRUE}. But it does not matter in what order the solutions are evaluated (or repaired or penalised), so the second loop can be vectorised. Examples are given in the vignettes and in the book. The respective \text{algo$\text{loopFun}$} must then be set to \text{FALSE}.

The objective function, the repair function and and the penalty function will be called as \text{fun(solution,\ldots)}.

The list \text{algo} contains the following items:

\[
\begin{align*}
\text{nP} & \quad \text{population size. Defaults to 100. Using default settings may not be a good idea.}
\end{align*}
\]
nG number of iterations. Defaults to 500. Using default settings may not be a good idea.
c1 the weight towards the individual’s best solution. Typically between 0 and 2; defaults to 1.
Using default settings may not be a good idea. In some cases, even negative values work well:
the solution is then driven off its past best position. For ‘simple’ problems, setting c1 to zero
may work well: the population moves then towards the best overall solution.
c2 the weight towards the populations’s best solution. Typically between 0 and 2; defaults to 1.
Using default settings may not be a good idea. In some cases, even negative values work well:
the solution is then driven off the population’s past best position.
inert the inertia weight (a scalar), which reduces velocity. Typically between 0 and 1. Default is
0.9.
initV the standard deviation of the initial velocities. Defaults to 1.
maxV the maximum (absolute) velocity. Setting limits to velocity is sometimes called velocity
clamping. Velocity is the change in a given solution in a given iteration. A maximum velocity
can be set so to prevent unreasonable velocities (‘overshooting’): for instance, if a decision
variable may lie between 0 and 1, then an absolute velocity much greater than 1 makes rarely
sense.
min, max vectors of minimum and maximum parameter values. The vectors min and max are
used to determine the dimension of the problem and to randomly initialise the population.
Per default, they are no constraints: a solution may well be outside these limits. Only if
algo$minmaxConstr is TRUE will the algorithm repair solutions outside the min and max range.
minmaxConstr if TRUE, algo$min and algo$max are considered constraints. Default is FALSE.
pen a penalty function. Default is NULL (no penalty).
repair a repair function. Default is NULL (no repairing).
changeV a function to change velocity. Default is NULL (no change). This function is called before
the velocity is added to the current solutions; it can be used to impose restrictions like changing
only a number of decision variables.
initP optional: the initial population. A matrix of size length(algo$min) times algo$nP, or a
function that creates such a matrix. If a function, it should take no arguments.
loopOF logical. Should the OF be evaluated through a loop? Defaults to TRUE.
loopPen logical. Should the penalty function (if specified) be evaluated through a loop? Defaults
to TRUE.
loopRepair logical. Should the repair function (if specified) be evaluated through a loop? Defaults
to TRUE.
loopChangeV logical. Should the changeV function (if specified) be evaluated through a loop?
Defaults to TRUE.
printDetail If TRUE (the default), information is printed. If an integer i greater then one, infor-
mation is printed at very i-th iteration.
printBar If TRUE (the default), a txtProgressBar (from package utils) is printed).
storeF If TRUE (the default), the objective function values for every solution in every generation
are stored and returned as matrix Fmat.
storeSolutions default is FALSE. If TRUE, the solutions (ie, decision variables) in every genera-
tion are stored as lists P and Pbest, both stored in the list xlist which the function returns. To
check, for instance, the solutions at the end of the 1th iteration, retrieve xlist[[c(1L,i)]]; the
best solutions at the end of this iteration are in xlist[[c(2L,i)]]; P[[i]] and Pbest[[i]]
will be matrices of size length(algo$min) times algo$nP.
classify Logical; default is FALSE. If TRUE, the result will have a class attribute TAopt attached. This feature is experimental: the supported methods may change without warning.

drop Default is TRUE. If FALSE, the dimension is not dropped from a single solution when it is passed to a function. (That is, the function will receive a single-column matrix.)

Value

Returns a list:

xbest the solution
OFvalue objective function value of best solution
popF a vector: the objective function values in the final population
Fmat if algo$storeF is TRUE, a matrix of size algo$nG times algo$nP. Each column contains the best objective function value found by the particular solution.
xlist if algo$storeSolutions is TRUE, a list that contains two lists P and Pbest of matrices, and a matrix initP (the initial solution); else NA.
initial.state the value of .Random.seed when PSopt was called.

Author(s)

Enrico Schumann

References


See Also

DEopt

Examples

## Least Median of Squares (LMS) estimation
genData <- function(nP, nO, ol, dy) {
  ## create dataset as in Salibian-Barrera & Yohai 2006
  ## nP = regressors, nO = number of obs
  ## ol = number of outliers, dy = outlier size
  mRN <- function(m, n) array(rnorm(m * n), dim = c(m, n))
  y <- mRN(nO, 1)
  X <- cbind(as.matrix(numeric(nO) + 1), mRN(nO, nP - 1L))
  zz <- sample(nO)
  z <- cbind(1, 100, array(0, dim = c(1L, nP - 2L)))
}
for (i in seq_len(ol)) {
    X[zz[i], ] <- z
    y[zz[i]] <- dy
}
list(X = X, y = y)
}

OF <- function(param, data) {
    X <- data$X
    y <- data$y
    aux <- as.vector(y) - X %*% param
    ## as.vector(y) for recycling (param is a matrix)
    aux <- aux * aux
    aux <- apply(aux, 2, sort, partial = data$h)
    aux[h, ]
}

nP <- 2L; nO <- 100L; ol <- 10L; dy <- 150
aux <- genData(nP, nO, ol, dy); X <- aux$X; y <- aux$y
h <- (nO + nP + 1L) %/% 2
data <- list(y = y, X = X, h = h)
algo <- list(min = rep(-10, nP), max = rep(10, nP),
            c1 = 1.0, c2 = 2.0,
            iner = 0.7, initV = 1, maxV = 3,
            nP = 100L, nG = 300L, loopOF = FALSE)

system.time(sol <- PSopt(OF = OF, algo = algo, data = data))
if (require("MASS", quietly = TRUE)) {
    ## for nsamp = "best", in this case, complete enumeration
    ## will be tried. See ?lqs
    system.time(test1 <- lqs(data$y ~ data$X[, -1L],
                             adjust = TRUE,
                             nsamp = "best",
                             method = "lqs",
                             quantile = data$h))
}

## check
x1 <- sort((y - X %*% as.matrix(sol$xbest))^2)[h]
cat("Particle Swarm\n",x1,"\n\n")

if (require("MASS", quietly = TRUE)) {
    x2 <- sort((y - X %*% as.matrix(coef(test1)))^2)[h]
cat("lqs\n",x2,"\n\n")
}
Description

Put–call parity

Usage

\texttt{putCallParity(what, call, put, S, X, tau, r, q = 0, tauD = 0, D = 0)}

Arguments

- \texttt{what}: character: what to compute. Currently only call or put are supported.
- \texttt{call}: call price
- \texttt{put}: put price
- \texttt{S}: underlier
- \texttt{X}: strike
- \texttt{tau}: time to expiry
- \texttt{r}: interest rate
- \texttt{q}: dividend rate
- \texttt{tauD}: numeric vector: time to dividend
- \texttt{D}: numeric vector: dividends

Details

Put–call parity only works for European options. The function is vectorised (like \texttt{vanillaOptionEuropean}), except for dividends.

Value

Numeric vector.

Author(s)

Enrico Schumann

References


Examples

```r
S <- 100; X <- 100; tau <- 1; r <- 0.02; q <- 0.0;
vol <- 0.3; D <- 20; tauD <- 0.5

call <- vanillaOptionEuropean(S, X, tau, r, q, vol^2,
  tauD = tauD, D = D, type = "call")$value

put <- vanillaOptionEuropean(S, X, tau, r, q, vol^2,
  tauD = tauD, D = D, type = "put")$value

# recover the call from the put (et vice versa)
all.equal(call, putCallParity("call", put = put, S=S, X=X, tau=tau,
  r=r, q=q, tauD=tauD, D=D))

all.equal(put, putCallParity("put", call = call, S=S, X=X, tau=tau,
  r=r, q=q, tauD=tauD, D=D))
```

```r
# Black--Scholes--Merton with 'callCF'
S <- 100; X <- 90; tau <- 1; r <- 0.02; q <- 0.08
v <- 0.2^2 ## variance, not volatility

(ccf <- callCF(cf = cfBSM, S = S, X = X, tau = tau, r = r, q = q,
  v = v, implVol = TRUE))

all.equal(ccf$value,
  vanillaOptionEuropean(S, X, tau, r, q, v, type = "call")$value)

all.equal(
  putCallParity("put", call=ccf$value, S=S, X=X, tau=tau, r=r, q=q),
  vanillaOptionEuropean(S, X, tau, r, q, v, type = "put")$value)
```

---

**qTable**

Prepare LaTeX Table with Quartile Plots

---

**Description**

The function returns the skeleton of a LaTeX tabular that contains the median, minimum and maximum of the columns of a matrix `X`. For each column, a quartile plot is added.

**Usage**

```r
qTable(X, xmin = NULL, xmax = NULL, labels = NULL, at = NULL,
  unitlength = "5cm", linethickness = NULL,
  cnames = colnames(X), circlesize = 0.01,
  xoffset = 0, yoffset = 0, dec = 2, filename = NULL,
  funs = list(median = median, min = min, max = max),
  tabular.format, skip = TRUE)
```

**Arguments**

- `X` a numeric matrix (or an object that can be coerced to a numeric matrix with `as.matrix`
### qTable

**xmin**  
optional: the minimum for the x-axis. See Details.

**xmax**  
optional: the maximum for the x-axis. See Details.

**labels**  
optional: labels for the x-axis.

**at**  
optional: where to put labels.

**unitlength**  
the unitlength for LaTeX's *picture* environment. See Details.

**linethickness**  
the linethickness for LaTeX's *picture* environment. See Details.

**cnames**  
the column names of \(X\)

**circlesize**  
the size of the circle in LaTeX's *picture* environment

**xoffset**  
defaults to 0. See Details.

**yoffset**  
defaults to 0. See Details.

**dec**  
the number of decimals

**filename**  
if provided, output is cat into a file

**funs**  
A list of functions; the functions should be named. Default is list(median = median, min = min, max = max)

**tabular.format**  
optional: character string like "rrrrr" that defines the format of the tabular.

**skip**  
>Adds a newline at the end of the tabular. Default is TRUE. (The behaviour prior to package version 0.27-0 corresponded to FALSE.)

### Details

The function creates a one-column character matrix that can be put into a LaTeX file (the matrix holds a tabular). It relies on LaTeX's *picture* environment and should work for LaTeX and pdfLaTeX. Note that the tabular needs generally be refined, depending on the settings and the data.

The tabular has one row for every column of \(X\) (and header and footer rows). A given row contains (per default) the median, the minimum and the maximum of the column; it also includes a *picture* environment the shows a quartile plot of the distribution of the elements in that column. Other functions can be specified via argument *funs*.

A number of parameters can be passed to LaTeX's *picture* environment: unitlength, xoffset, yoffset, linethickness. Sizes and lengths are functions of unitlength (linethickness is an exception; and while circlesize is a multiple of unitlength, it will not translate into an actual diameter of more than 14mm).

The whole tabular environment is put into curly brackets so that the settings do not change settings elsewhere in the LaTeX document.

If xmin, xmax, labels and at are not specified, they are computed through a call to *pretty* from the base package. If limits are specified, then both xmin and xmax must be set; if labels are used, then both labels and at must be specified.

To use the function in a vignette, use cat(tTable(X)) (and results=tex in the code chunk options). The vignette qTableEx shows some examples.

### Value

A matrix of mode character. If filename is specified then qTable will have the side effect of writing a textfile with a LaTeX tabular.
Note

qTable returns a raw draft of a table for LaTeX. Please, spend some time on making it pretty.

Author(s)

Enrico Schumann

References


Examples

```r
x <- rnorm(100, mean = 0, sd = 2)
y <- rnorm(100, mean = 1, sd = 2)
z <- rnorm(100, mean = 1, sd = 0.5)
X <- cbind(x, y, z)
res <- qTable(X)
print(res)
cat(res)

## Not run:
## show vignette with examples
qt <- vignette("qTableEx", package = "NMOF")
print(qt)
edit(qt)

## create a simple LaTeX file 'test.tex':
## ---
## \documentclass{article}
## \begin{document}
## \input{res.tex}
## \end{document}
## ---
res <- qTable(X, filename = "res.tex", yoffset = -0.025, unitlength = "5cm",
circle = 0.0125, xmin = -10, xmax = 10, dec = 2)
## End(Not run)
```
randomReturns

Create a Random Returns

Description
Create a matrix of random returns.

Usage
randomReturns(na, ns, sd, mean = 0, rho = 0)

Arguments
\begin{itemize}
\item \texttt{na} \quad number of assets
\item \texttt{ns} \quad number of return scenarios
\item \texttt{sd} \quad the standard deviation: either a single number or a vector of length \texttt{na}
\item \texttt{mean} \quad the mean return: either a single number or a vector of length \texttt{na}
\item \texttt{rho} \quad correlation: either a scalar (i.e. a constant pairwise correlation) or a correlation matrix
\end{itemize}

Details
The function corresponds to the function \texttt{random\_returns}, described in the second edition of \textit{NMOF} (the book).

Value
A \texttt{numeric matrix} of size \texttt{na} times \texttt{ns}

Note
The function corresponds to the function \texttt{random\_returns}, described in the second edition of \textit{NMOF} (the book).

Author(s)
Enrico Schumann

References

See Also

mc

Examples

## a small experiment: when computing minimum-variance portfolios
## for correlated assets, how many large positions are in the portfolio?

na <- 100  ## number of assets
inc <- 5   ## minimum of assets to include

n <- numeric(10)
for (i in seq_along(n)) {
  R <- randomReturns(na = na,
                      ns = 500,
                      sd = seq(.2/.16, .5/.16, length.out = 100),
                      rho = 0.5)
  n[i] <- sum(minvar(cov(R), wmax = 1/inc) > 0.01)
}
summary(n)

repairMatrix

Repair an Indefinite Correlation Matrix

Description

The function ‘repairs’ an indefinite correlation matrix by replacing its negative eigenvalues by zero.

Usage

repairMatrix(C, eps = 0)

Arguments

C a correlation matrix
eps a small number

Details

The function ‘repairs’ a correlation matrix: it replaces negative eigenvalues with \( \text{eps} \) and rescales the matrix such that all elements on the main diagonal become unity again.

Value

Returns a numeric matrix.
Note

This function may help to cure a numerical problem, but it will rarely help to cure an empirical problem. (Garbage in, garbage out.)
See also the function nearPD in the Matrix package.

Author(s)

Enrico Schumann

References


Examples

```r
## example: build a portfolio of three assets
C <- c(1,.9,.9,.9,1,.2,.9,.2,1)
dim(C) <- c(3L, 3L)
eigen(C, only.values = TRUE)

vols <- c(.3, .3, .3)  # volatilities
S <- C * outer(vols,vols)  # covariance matrix
w <- c(-1, 1, 1)  # a portfolio
w %*% S %*% w  # variance of portfolio is negative!
sqrt(as.complex(w %*% S %*% w))

S <- repairMatrix(C) * outer(vols,vols)
w %*% S %*% w  # more reasonable
sqrt(w %*% S %*% w)
```

resampleC

Resample with Specified Rank Correlation

Description

Resample with replacement from a number of vectors; the sample will have a specified rank correlation.

Usage

`resampleC(..., size, cormat)`
Arguments

... numeric vectors; they need not have the same length.
size an integer: the number of samples to draw
cormat the rank correlation matrix

Details

See Gilli, Maringer and Schumann (2011), Section 7.1.2. The function samples with replacement from the vectors passed through .... The resulting samples will have an (approximate) rank correlation as specified in cormat.

The function uses the eigenvalue decomposition to generate the correlation; it will not break down in case of a semidefinite matrix. If an eigenvalue of cormat is smaller than zero, a warning is issued (but the function proceeds).

Value

a numeric matrix with size rows. The columns contain the samples; hence, there will be as many columns as vectors passed through ....

Author(s)

Enrico Schumann

References


See Also

repairMatrix

Examples

```r
## a sample
v1 <- rnorm(20)
v2 <- runif(50)
v3 <- rbinom(100, size = 50, prob = 0.4)

## a correlation matrix
cormat <- array(0.5, dim = c(3, 3))
diag(cormat) <- 1

cor(resampleC(a = v1, b = v2, v3, size = 100, cormat = cormat),
    method = "spearman")
```
Description

The function provides a simple wrapper for the optimisation algorithms in the package.

Usage

restartOpt(fun, n, OF, algo, ..., 
method = c("loop", "multicore", "snow"), 
mc.control = list(), cl = NULL, 
best.only = FALSE)

Arguments

fun  the optimisation function: DEopt, GAopt, LSopt, TAopt or PSopt
n  the number of restarts
OF  the objective function
algo  the list algo that is passed to the particular optimisation function
...  additional data that is passed to the particular optimisation function
method  can be loop (the default), multicore or snow. See Details.
m.c.control  a list containing settings that will be passed to mclapply if method is multicore. Must be a list of named elements. See the documentation of mclapply.
cl  default is NULL. If method snow is used, this must be a cluster object or an integer (the number of cores).
best.only  if TRUE, only the best run is reported. Default is FALSE.

Details

The function returns a list of lists. If a specific starting solution is passed, all runs will start from this solution. If this is not desired, initial solutions can be created randomly. This is done per default in DEopt, GAopt and PSopt, but LSopt and TAopt require to specify a starting solution.

In case of LSopt and TAopt, the passed initial solution algo$x0 is checked with is.function: if TRUE, the function is evaluated in each single run. For DEopt, GAopt and PSopt, the initial solution (which also can be a function) is specified with algo$initP.

The argument method determines how fun is evaluated. Default is loop. If method is "multicore", function mclapply from package parallel is used. Further settings for mclapply can be passed through the list mc.control. If multicore is chosen but the functionality is not available, then method will be set to loop and a warning is issued. If method == "snow", function clusterApply from package parallel is used. In this case, the argument cl must either be a cluster object (see the documentation of clusterApply) or an integer. If an integer, a cluster will be set up via makeCluster(c(rep("localhost", cl)), type = "SOCK"), and stopCluster is called when the function is exited. If snow is chosen but parallel is not available or cl is not specified, then method will be set to loop and a warning is issued. In case that cl is an cluster object, stopCluster will not be called automatically.
**Value**

If `best.only` is FALSE (the default), the function returns a list of n lists. Each of the n lists stores the output of one of the runs.

If `best.only` is TRUE, only the best restart is reported. The returned list has the structure specific to the used method.

**Author(s)**

Enrico Schumann

**References**


**See Also**

`DEopt`, `GAopt`, `LSopt`, `PSopt`, `TAopt`

**Examples**

```r
## see example(DEopt)
algo <- list(nP = 50L,
F = 0.5,
CR = 0.9,
min = c(-10, -10),
max = c(10, 10),
printDetail = FALSE,
printBar = FALSE)

## choose a larger 'n' when you can afford it
algo$nG <- 100L
res100 <- restartOpt(DEopt, n = 5L, OF = tfTrefethen, algo = algo)
res100F <- sapply(res100, `[[`, "OFvalue")

algo$nG <- 200L
res200 <- restartOpt(DEopt, n = 5L, OF = tfTrefethen, algo = algo)
res200F <- sapply(res200, `[[`, "OFvalue")

xx <- pretty(c(res100F, res200F, -3.31))
plot(ecdf(res100F), main = "optimum is -3.306",
xlim = c(xx[1L], tail(xx, 1L)))
abline(v = -3.3069, col = "red")  ## optimum
lines(ecdf(res200F), col = "blue")
legend(x = "right", box.lty = 0, lty = 1,
legend = c("optimum", "100 generations", "200 generations"),
pch = c(NA, 19, 19), col = c("red", "black", "blue"))
```
## a 'best-of-N' strategy: given a sample x of objective function values, compute the probability that, after N draws, we have at least one realisation not worse than X

\[
x <- c(0.1, 0.3, 0.5, 0.5, 0.6)
\]

\[
\text{bestofN} <- \text{function}(x, N) \{
  \text{nx} <- \text{length}(x)
  \text{function}(X)
    1 - (\text{sum}(x > X)/\text{nx})^N
\}
\]

\[
\text{bestofN}(x, 2)
\]

\[
\text{bestofN}(x, 5)
\]

\[
\text{bestofN}(0.15)
\]

\[
\text{bestofN}(0.15)
\]

## Not run:

## with R >= 2.13.0 and the compiler package
\[
\text{algo$nG} <- 100L
\]

\[
\text{system.time(res100 <- restartOpt(DEopt, n = 10L, OF = tfTrefethen, algo = algo))}
\]

require("compiler")

\[
\text{enableJIT(3)}
\]

\[
\text{system.time(res100 <- restartOpt(DEopt, n = 10L, OF = tfTrefethen, algo = algo))}
\]

## End(Not run)

---

**Ritter**

Download Jay Ritter’s IPO Data

**Description**

Download IPO data provided by Jay Ritter and transform them into a data frame.

**Usage**

```r
Ritter(dest.dir, url = "https://site.warrington.ufl.edu/ritter/files/IPO-age.xlsx")
```

**Arguments**

- `dest.dir` character: a path to a directory
- `url` the data URL

**Details**

The function downloads IPO data provided by Jay R. Ritter [https://site.warrington.ufl.edu/ritter](https://site.warrington.ufl.edu/ritter). Since the data are provided in Excel format, package `openxlsx` is required.
The downloaded Excel gets a date prefix (today in format YYYYMMDD) and is stored in directory dest.dir. Before any download is attempted, the function checks whether a file with today’s prefix exist in dest.dir; if yes, this file is used.

Value

a data.frame:

<table>
<thead>
<tr>
<th>CUSIP</th>
<th>CUSIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offer date</td>
<td>a Date</td>
</tr>
<tr>
<td>Company name</td>
<td>character: Company name</td>
</tr>
<tr>
<td>Ticker</td>
<td>character: Ticker</td>
</tr>
<tr>
<td>Founding</td>
<td>Founding year</td>
</tr>
<tr>
<td>PERM</td>
<td>PERM</td>
</tr>
<tr>
<td>VC dummy</td>
<td>VC Dummy</td>
</tr>
<tr>
<td>Rollup</td>
<td>Rollup</td>
</tr>
<tr>
<td>Dual</td>
<td>Dual</td>
</tr>
<tr>
<td>Post-issue shares</td>
<td>Post-issue shares</td>
</tr>
<tr>
<td>Internet</td>
<td>Internet</td>
</tr>
</tbody>
</table>

Author(s)

Enrico Schumann

References

https://site.warrington.ufl.edu/ritter/ipo-data/


See Also

French, Shiller

Examples

```r
## Not run:
archive.dir <- "~/Downloads/Ritter"
if (!dir.exists(archive.dir))
  dir.create(archive.dir)
Ritter(archive.dir)
## End(Not run)
```
Simulated-Annealing Information

Description

The function can be called from the objective and neighbourhood function during a run of \texttt{SAopt}; it provides information such as the current iteration, the current solution, etc.

Usage

\begin{verbatim}
SA.info(n = 0L)
\end{verbatim}

Arguments

- \texttt{n} generational offset; see Details.

Details

\textbf{This function is still experimental.}

The function can be called in the neighbourhood function or the objective function during a run of \texttt{SAopt}. It evaluates to a list with information about the state of the optimisation run, such as the current iteration or the currently best solution.

\texttt{SA.info} relies on \texttt{parent.frame} to retrieve its information. If the function is called within another function within the neighbourhood or objective function, the argument \texttt{n} needs to be increased.

Value

A list

- \texttt{calibration} logical: whether the algorithm is calibrating the acceptance probability
- \texttt{iteration} current iteration
- \texttt{step} current step for the given temperature level
- \texttt{temperature} current temperature (the number, not the value)
- \texttt{xbest} the best solution found so far

Author(s)

Enrico Schumann

References


### MINIMAL EXAMPLE for SAopt

#### the objective function evaluates to a constant
```r
defun <- function(x)
  0
```

#### the neighbourhood function does not even change
```r
defnb <- function(x) {
  info <- SA.info()
  cat("current step ", info$step,
       "| current iteration ", info$iteration, "n")
  x
}
```

#### run SA
```r
talgo <- list(nS = 5, nT = 2, nD = 10,
              initT = 1,
              x0 = rep(0, 5),
              neighbour = nb,
              printBar = FALSE)
ignore <- SAopt(fun, algo)
```
Details

Simulated Annealing (SA) changes an initial solution iteratively; the algorithm stops after a fixed number of iterations. Conceptually, SA consists of a loop than runs for a number of iterations. In each iteration, a current solution \( x_c \) is changed through a function \( \text{algo$\text{neighbour}(...) \rightarrow x_n \in \mathbb{R}^k \) \}. If this new (or neighbour) solution \( x_n \) is not worse than \( x_c \), ie, if \( \text{OF}(x_n,\ldots) \leq \text{OF}(x_c,\ldots) \), then \( x_n \) replaces \( x_c \). If \( x_n \) is worse, it still replaces \( x_c \), but only with a certain probability. This probability is a function of the degree of the deterioration (the greater, the less likely the new solution is accepted) and the current iteration (the longer the algorithm has already run, the less likely the new solution is accepted).

The list \( \text{algo} \) contains the following items.

- \( nS \) The number of steps per temperature. The default is 1000; but this setting depends very much on the problem.
- \( nT \) The number of temperatures. Default is 10.
- \( nI \) Total number of iterations, with default NULL. If specified, it will override \( nS \) with \( \text{ceiling}(nI/nT) \). Using this option makes it easier to compare and switch between functions \( \text{LSopt, TAopt and SAopt} \).
- \( nD \) The number of random steps to calibrate the temperature. Defaults to 2000.
- \( \text{initT} \) Initial temperature. Defaults to NULL, in which case it is automatically chosen so that \( \text{initProb} \) is achieved.
- \( \text{finalT} \) Final temperature. Defaults to 0.
- \( \text{alpha} \) The cooling constant. The current temperature is multiplied by this value. Default is 0.9.
- \( mStep \) Step multiplier. The default is 1, which implies constant number of steps per temperature. If greater than 1, the step number \( nS \) is increased to \( m*nS \) (and rounded).
- \( x0 \) The initial solution. If this is a function, it will be called once without arguments to compute an initial solution, ie, \( x0 <-\text{algo$x0()} \). This can be useful when the routine is called in a loop of restarts, and each restart is to have its own starting value.
- \( \text{neighbour} \) The neighbourhood function, called as \( \text{neighbour}(x,\ldots) \). Its first argument must be a solution \( x \); it must return a changed solution.
- \( \text{printDetail} \) If \( \text{TRUE} \) (the default), information is printed. If an integer \( i \) greater then one, information is printed at every \( i \)th iteration.
- \( \text{printBar} \) If \( \text{TRUE} \) (default is \( \text{FALSE} \)), a \text{txtProgressBar} \ (from package \text{utils}) is printed. The progress bar is not shown if \( \text{printDetail} \) is an integer greater than 1.
- \( \text{storeF} \) if \( \text{TRUE} \) (the default), the objective function values for every solution in every generation are stored and returned as matrix \( \text{Fmat} \).
- \( \text{storeSolutions} \) Default is \( \text{FALSE} \). If \( \text{TRUE} \), the solutions (ie, decision variables) in every generation are stored and returned in list \( \text{xlist} \) (see Value section below). To check, for instance, the current solution at the end of the 4th generation, retrieve \( \text{xlist[[c(2L,4)]]} \).
- \( \text{classify} \) Logical; default is \( \text{FALSE} \). If \( \text{TRUE} \), the result will have a class attribute \( \text{SAopt} \) attached.
- \( \text{OF.target} \) Numeric; when specified, the algorithm will stop when an objective-function value as low as \( \text{OF.target} \) (or lower) is achieved. This is useful when an optimal objective-function value is known: the algorithm will then stop and not waste time searching for a better solution.

At the minimum, \( \text{algo} \) needs to contain an initial solution \( x0 \) and a \( \text{neighbour} \) function.

The total number of iterations equals \( \text{algo$nT \times algo$nS} \) (plus possibly \( \text{algo$nD} \)).
SAopt returns a list with five components:

- **xbest**: the solution
- **OFvalue**: objective function value of the solution, i.e., \( OF(x_{\text{best}}, \ldots) \)
- **Fmat**: if `algo$storeF` is TRUE, a matrix with one row for each iteration (excluding the initial `algo$nD` steps) and two columns. The first column contains the objective function values of the neighbour solution at a given iteration; the second column contains the value of the current solution. Since SA can walk away from locally-optimal solutions, the best solution can be monitored through `cummin(Fmat[,2L])`.
- **xlist**: if `algo$storeSolutions` is TRUE, a list; else `NA`. Contains the neighbour solutions at a given iteration \( (x_n) \) and the current solutions \( (x_c) \). Example: \( Fmat[i,2L] \) is the objective function value associated with \( xlist[[c(2L,i)]] \).
- **initial.state**: the value of `.Random.seed` when the function was called.

If `algo$classify` was set to TRUE, the resulting list will have a class attribute `TAopt`.

**Note**

If the `...` argument is used, then all the objects passed with `...` need to go into the objective function and the neighbourhood function. It is recommended to collect all information in a list `myList` and then write `OF` and `neighbour` so that they are called as `OF(x,myList)` and `neighbour(x,myList)`. Note that `x` need not be a vector but can be any data structure (e.g., a matrix or a list).

Using an initial and final temperature of zero means that SA will be equivalent to a Local Search. The function `LSopt` may be preferred then because of smaller overhead.

**Author(s)**

Enrico Schumann

**References**


**See Also**

- `LSopt, TAopt, restartOpt`
Examples

## Aim: given a matrix x with n rows and 2 columns,
## divide the rows of x into two subsets such that
## in one subset the columns are highly correlated,
## and in the other lowly (negatively) correlated.
## constraint: a single subset should have at least 40 rows

## create data with specified correlation
n <- 100L
rho <- 0.7
C <- matrix(rho, 2L, 2L); diag(C) <- 1
x <- matrix(rnorm(n * 2L), n, 2L) %*% chol(C)

## collect data
data <- list(x = x, n = n, nmin = 40L)

## a random initial solution
x0 <- runif(n) > 0.5

## a neighbourhood function
neighbour <- function(xc, data) {
  xn <- xc
  p <- sample.int(data$n, size = 1L)
  xn[p] <- abs(xn[p] - 1L)
  # reject infeasible solution
  c1 <- sum(xn) >= data$nmin
  c2 <- sum(xn) <= (data$n - data$nmin)
  if (c1 && c2) res <- xn else res <- xc
  as.logical(res)
}

## check (should be 1 FALSE and n-1 TRUE)
x0 == neighbour(x0, data)

## objective function
OF <- function(xc, data)
  -abs(cor(data$x[xc, ])[1L, 2L] - cor(data$x[!xc, ])[1L, 2L])

## check
OF(x0, data)

## plot data
par(mfrow = c(1,3), bty = "n")
plot(data$x,
     xlim = c(-3,3), ylim = c(-3,3),
     main = "all data", col = "darkgreen")

## plot data
par(mfrow = c(1,3), bty = "n")
plot(data$x,
     xlim = c(-3,3), ylim = c(-3,3),
     main = "all data", col = "darkgreen")

## plot data
par(mfrow = c(1,3), bty = "n")
plot(data$x,
     xlim = c(-3,3), ylim = c(-3,3),
     main = "all data", col = "darkgreen")

## Local Search
algo <- list(nS = 3000L,
             neighbour = neighbour,
\[ x_0 = x_0, \]
\[ \text{printBar} = \text{FALSE} \]
\[ \text{sol1} \leftarrow \text{LSopt(OF, algo = algo, data=data)} \]
\[ \text{sol1$OFvalue} \]

\#
\#
\*Simulated Annealing*
\#
\[ \text{algo$nT} \leftarrow 10L \]
\[ \text{algo$nS} \leftarrow \text{ceiling(algo$nS/algo$nT)} \]
\[ \text{sol} \leftarrow \text{SAopt(OF, algo = algo, data = data)} \]
\[ \text{sol$OFvalue} \]
\[ \text{c1} \leftarrow \text{cor(data$x[sol$xbest, ])}[1L, 2L] \]
\[ \text{c2} \leftarrow \text{cor(data$x[!sol$xbest, ])}[1L, 2L] \]
\[ \text{lines(data$x[sol$xbest, ], type = "p", col = "blue")} \]
\[ \text{plot(data$x[sol$xbest, ], col = "blue",} \]
\[ \text{xlim = c(-3,3), ylim = c(-3,3),} \]
\[ \text{main = paste("subset 1, corr.", format(c1, digits = 3))} \]
\[ \text{plot(data$x[!sol$xbest, ], col = "darkgreen",} \]
\[ \text{xlim = c(-3,3), ylim = c(-3,3),} \]
\[ \text{main = paste("subset 2, corr.", format(c2, digits = 3))} \]
\[ \text{## compare LS/SA} \]
\[ \text{par(mfrow = c(1,1), bty = "n")} \]
\[ \text{plot(sol1$Fmat[, 2L], type = "l", ylim=c(-1.5, 0.5),} \]
\[ \text{ylab = "OF", xlab = "Iterations")} \]
\[ \text{lines(sol1$Fmat[, 2L], type = "l", col = "blue")} \]
\[ \text{legend(x = "topright", legend = c("LS", "SA"),} \]
\[ \text{lty = 1, lwd = 2, col = c("black", "blue"))} \]

---

**Shiller**

**Download Robert Shiller's Data**

**Description**

Download the data provided by Robert Shiller and transform them into a data frame.

**Usage**


**Arguments**

- `dest.dir`: character: a path to a directory
- `url`: the data URL
Details

The function downloads US stock-market data provided by Robert Shiller which he used in his book ‘Irrational Exhuberance’. Since the data are provided in Excel format, package readxl is required.

The downloaded Excel gets a date prefix (today in format YYYYMMDD) and is stored in directory dest.dir. Before any download is attempted, the function checks whether a file with today’s prefix exist in dest.dir; if yes, the file is used.

Value

a data.frame:

- Date: end of month
- Price: numeric
- Dividend: numeric
- Earnings: numeric
- CPI: numeric
- Long Rate: numeric
- Real Price: numeric
- Real Dividend: numeric
- Real Earnings: numeric
- CAPE: numeric

Author(s)

Enrico Schumann

References


See Also

French

Examples

```r
## Not run:
archive.dir <- "~/Downloads/Shiller"
if (!dir.exists(archive.dir))
  dir.create(archive.dir)
Shiller(archive.dir)

## End(Not run)
```
showExample

Display Code Examples

Description

Display the code examples from 'Numerical Methods and Optimization and Finance'.

Usage

showExample(file = "", chapter = NULL, showfile = TRUE,
      includepaths = FALSE, edition = 2, search,
      ..., ignore.case = TRUE)

showChapterNames(edition = 2)

Arguments

file a character vector of length one. See Details.
chapter optional: a character vector of length one, giving the chapter name (see Details),
or an integer, indicating a chapter number. Default is NULL: look in all chapters.
showfile Should the file be displayed with file.show? Defaults to TRUE. A file will be
displayed only if one single file only is identified by file and chapter.
includepaths Should the file paths be displayed? Defaults to FALSE.
... Arguments passed to grepl; see Details.
edition an integer: 1 and 2 are supported
search a regular expression: search in the code files. Not supported yet.
ignore.case passed to grepl; see Examples. Default is TRUE (which is much more helpful
than the default FALSE before package version 2)

Details

showExample matches the specified file argument against the available file names via grepl(file, all.filenames, ignore.case, ...). If chapter is specified, a second match is performed, grepl(chapter, all.chapternames, ignore.case, ...). The chapter names are those in the book (e.g., 'Modeling dependencies').
The selected files are then those for which file name and chapter name could be matched.

Value

showExample returns a data.frame of at least two character vectors, Chapter and File. If includepaths
is TRUE, Paths are included. If no file is found, the data.frame has zero rows. If a single file is
identified and showfile is TRUE, the function has the side effect of displaying that file.
showChapterNames returns a character vector: the names of the book’s chapters.
**Note**

The behaviour of the function changed slightly with version 2.0 to accommodate the code examples of the second edition of the book. Specifically, the function gained an argument edition, which defaults to 2. Also, the default for `ignore.case` was changed to `TRUE`. To get back the old behaviour of the function, set `edition` to 1 and `ignore.case` to `FALSE`.

The code files can also be downloaded from [https://gitlab.com/NMOF](https://gitlab.com/NMOF).

**Author(s)**

Enrico Schumann

**References**


**Examples**

```r
## list all files
showExample() ## 2nd edition is default
showExample(edition = 1)

## list specific files
showExample("Appendix")
showExample("Backtesting")
showExample("Heuristics")

showExample("tutorial") ## matches against filename
showExample(chapter = 13)
showExample(chapter = "tutorial")

## show where a file is installed
showExample(chapter = "portfolio", includepaths = TRUE)

## first edition
showExample("equations.R", edition = 1)
showExample("example", chapter = "portfolio", edition = 1)

showExample("example", chapter = 13, edition = 1)
showExample("example", chapter = showChapterNames(1)[13L], edition = 1)
```
Threshold-Accepting Information

Description

The function can be called from the objective and neighbourhood function during a run of \texttt{TAopt}; it provides information such as the current iteration, the current solution, etc.

Usage

\begin{verbatim}
TA.info(n = 0L)
\end{verbatim}

Arguments

- \texttt{n} generational offset; see Details.

Details

\textbf{This function is still experimental.}

The function can be called in the neighbourhood function or the objective function during a run of \texttt{TAopt}. It evaluates to a list with the state of the optimisation run, such as the current iteration.

\texttt{TA.info} relies on \texttt{parent.frame} to retrieve its information. If the function is called within another function in the neighbourhood or objective function, the argument \texttt{n} needs to be increased.

Value

A list

- \texttt{OF.sampling} logical: if \texttt{TRUE}, is the algorithm sampling the objective function to compute thresholds; otherwise (i.e. during the actual optimisation) \texttt{FALSE}
- \texttt{iteration} current iteration
- \texttt{step} current step (i.e. for a given threshold)
- \texttt{threshold} current threshold (the number, not the value)
- \texttt{xbest} the best solution found so far
- \texttt{OF.xbest} objective function value of best solution

Author(s)

Enrico Schumann

References


See Also

TAopt

Examples

### MINIMAL EXAMPLE for TAopt

```r
## objective function evaluates to a constant
fun <- function(x) 0

## neighbourhood function does not even change the solution,
## but it reports information
nb <- function(x) {
  tmp <- TA.info()
  cat("current threshold ", tmp$threshold,
       "| current step ", tmp$step,
       "| current iteration ", tmp$iteration, "\n")
  x
}

## run TA
algo <- list(nS = 5,
              nT = 2,
              nD = 3,
              x0 = rep(0, 5),
              neighbour = nb,
              printBar = FALSE,
              printDetail = FALSE)
ignore <- TAopt(fun, algo)

## printed output:
## current threshold      | current step      | current iteration NA
## current threshold      | current step      | current iteration NA
## current threshold      | current step      | current iteration NA
## current threshold 1    | current step 1    | current iteration 1
## current threshold 1    | current step 2    | current iteration 2
## current threshold 1    | current step 3    | current iteration 3
## current threshold 1    | current step 4    | current iteration 4
## current threshold 1    | current step 5    | current iteration 5
## current threshold 2    | current step 1    | current iteration 6
## current threshold 2    | current step 2    | current iteration 7
## current threshold 2    | current step 3    | current iteration 8
## current threshold 2    | current step 4    | current iteration 9
## current threshold 2    | current step 5    | current iteration 10
```

---

TAopt

Optimisation with Threshold Accepting
**TAopt**

**Description**

The function implements the Threshold Accepting algorithm.

**Usage**

```r
TAopt(OF, algo = list(), ...)
```

**Arguments**

- **OF** The objective function, to be minimised. Its first argument needs to be a solution `x`; it will be called as `OF(x, ...)`.  
- **algo** A list of settings for the algorithm. See Details.  
- **...** other variables passed to `OF` and `algo$neighbour`. See Details.

**Details**

Threshold Accepting (TA) changes an initial solution iteratively; the algorithm stops after a fixed number of iterations. Conceptually, TA consists of a loop than runs for a number of iterations. In each iteration, a current solution `xc` is changed through a function `algo$neighbour`. If this new (or neighbour) solution `xn` is not worse than `xc`, i.e., if `OF(xn, ...) <= OF(xc, ...)`, then `xn` replaces `xc`. If `xn` is worse, it still replaces `xc` as long as the difference in 'quality' between the two solutions is less than a threshold `tau`; more precisely, as long as `OF(xn, ...) - tau <= OF(xc, ...)`. Thus, we also accept a new solution that is worse than its predecessor; just not too much worse. The threshold is typically decreased over the course of the optimisation. For zero thresholds TA becomes a stochastic local search.

The thresholds can be passed through the list `algo` (see below). Otherwise, they are automatically computed through the procedure described in Gilli et al. (2006). When the thresholds are created automatically, the final threshold is always zero.

The list `algo` contains the following items.

- **nS** The number of steps per threshold. The default is 1000; but this setting depends very much on the problem.  
- **nT** The number of thresholds. Default is 10; ignored if `algo$vT` is specified.  
- **nI** Total number of iterations, with default `NULL`. If specified, it will override `nS` with `ceiling(nI/nT)`. Using this option makes it easier to compare and switch between functions `LSopt`, `TAopt` and `SAopt`.  
- **nD** The number of random steps to compute the threshold sequence. Defaults to 2000. Only used if `algo$vT` is `NULL`.  
- **q** The highest quantile for the threshold sequence. Defaults to 0.5. Only used if `algo$vT` is `NULL`. If `q` is zero, `TAopt` will run with `algo$nT` zero-thresholds (i.e., like a Local Search).  
- **x0** The initial solution. If this is a function, it will be called once without arguments to compute an initial solution, i.e., `x0 <- algo$x0()`. This can be useful when the routine is called in a loop of restarts, and each restart is to have its own starting value.

- **vT** The thresholds. A numeric vector. If `NULL` (the default), `TAopt` will compute `algo$nT` thresholds. Passing threshold can be useful when similar problems are handled. Then the time to sample the objective function to compute the thresholds can be saved (i.e., we save `algo$nD`
function evaluations). If the thresholds are computed and algo$printDetail is TRUE, the
time required to evaluate the objective function will be measured and an estimate for the re-
mainling computing time is issued. This estimate is often very crude.

neighbour The neighbourhood function, called as neighbour(x,...). Its first argument must be
a solution x; it must return a changed solution.

printDetail If TRUE (the default), information is printed. If an integer i greater then one, informa-
tion is printed at very i-th iteration.

printBar If TRUE (default is FALSE), a txtProgressBar (from package utils) is printed. The
progress bar is not shown if printDetail is an integer greater than 1.

scale The thresholds are multiplied by scale. Default is 1.

drop0 When thresholds are computed, should zero values be dropped from the sample of objective-
function values? Default is FALSE.

stepUp Defaults to 0. If an integer greater than zero, then the thresholds are recycled, ie, vT
is replaced by rep(vT,algo$stepUp + 1) (and the number of thresholds will be increased by
algo$nT times algo$stepUp). This option works for supplied as well as computed thresholds.
Practically, this will have the same effect as restarting from a returned solution. (In Simulated
Annealing, this strategy goes by the name of 'reheating'.)

thresholds.only Defaults to FALSE. If TRUE, compute only threshold sequence, but do not actu-
ally run TA.

storeF if TRUE (the default), the objective function values for every solution in every generation
are stored and returned as matrix Fmat.

storeSolutions Default is FALSE. If TRUE, the solutions (ie, decision variables) in every genera-
tion are stored and returned in list xlist (see Value section below). To check, for instance,
the current solution at the end of the i-th generation, retrieve xlist[[c(2L,i)]].

classify Logical; default is FALSE. If TRUE, the result will have a class attribute TAopt attached.
This feature is experimental: the supported methods (plot, summary) may change without
warning.

OF.target Numeric; when specified, the algorithm will stop when an objective-function value as
low as OF.target (or lower) is achieved. This is useful when an optimal objective-function
value is known: the algorithm will then stop and not waste time searching for a better solution.

At the minimum, algo needs to contain an initial solution x0 and a neighbour function.
The total number of iterations equals algo$nT times (algo$stepUp + 1) times algo$nS (plus possi-
ibly algo$nD).

Value

TAopt returns a list with four components:

xbest the solution

OFValue objective function value of the solution, ie, OF(xbest,...)

Fmat if algo$storeF is TRUE, a matrix with one row for each iteration (excluding the
initial algo$nD steps) and two columns. The first column contains the objective
function values of the neighbour solution at a given iteration; the second column
contains the value of the current solution. Since TA can walk away from locally-
optimal solutions, the best solution can be monitored through cummin(Fmat[,2L]).
if algo$storeSolutions is TRUE, a list; else NA. Contains the neighbour solutions at a given iteration ($x_n$) and the current solutions ($x_c$). Example: $F_{\text{mat}}[i,2L]$ is the objective function value associated with $x_{\text{list}}[[c(2L,i)]]$.

initial.state the value of .Random.seed when the function was called.

If algo$classify was set to TRUE, the resulting list will have a class attribute TAopt.

Note

If the ... argument is used, then all the objects passed with ... need to go into the objective function and the neighbourhood function. It is recommended to collect all information in a list myList and then write $OF$ and $\text{neighbour}$ so that they are called as $OF(x,myList)$ and $\text{neighbour}(x,myList)$. Note that $x$ need not be a vector but can be any data structure (eg. a matrix or a list).

Using thresholds of size 0 makes TA run as a Local Search. The function LSopt may be preferred then because of smaller overhead.

Author(s)

Enrico Schumann

References


See Also

LSopt, restartOpt
Examples

## Aim: given a matrix \( x \) with \( n \) rows and 2 columns,
## divide the rows of \( x \) into two subsets such that
## in one subset the columns are highly correlated,
## and in the other lowly (negatively) correlated.
## constraint: a single subset should have at least 40 rows

## create data with specified correlation
\( n \leftarrow 100L \)
\( \rho \leftarrow 0.7 \)
\( C \leftarrow \text{matrix}(\rho, 2L, 2L); \; \text{diag}(C) \leftarrow 1 \)
\( x \leftarrow \text{matrix}(\text{rnorm}(n * 2L), n, 2L) \; \%\% \; \text{chol}(C) \)

## collect data
\( \text{data} \leftarrow \text{list}(x = x, n = n, \text{min}n = 40L) \)

## a random initial solution
\( x0 \leftarrow \text{runif}(n) > 0.5 \)

## a neighbourhood function
\( \text{neighbour} \leftarrow \text{function}(\text{xc}, \text{data}) \{ \)
\( \quad \text{xn} \leftarrow \text{xc} \)
\( \quad \text{p} \leftarrow \text{sample.int}(\text{data}$n, \text{size} = 1L) \)
\( \quad \text{xn}[\text{p}] \leftarrow \text{abs}(\text{xn}[\text{p}] - 1L) \)
\( \# \text{ reject infeasible solution} \)
\( \quad \text{c1} \leftarrow \text{sum}(\text{xn}) \geq \text{data}$\text{min}n \)
\( \quad \text{c2} \leftarrow \text{sum}(\text{xn}) \leq (\text{data}$n - \text{data}$\text{min}n) \)
\( \quad \text{if} \; (\text{c1} \&\& \text{c2}) \; \text{res} \leftarrow \text{xn} \; \text{else} \; \text{res} \leftarrow \text{xc} \)
\( \quad \text{as.logical}(\text{res}) \}

## check (should be 1 FALSE and \( n-1 \) TRUE)
\( x0 \leftarrow \text{neighbour}(x0, \text{data}) \)

## objective function
\( \text{OF} \leftarrow \text{function}(\text{xc}, \text{data}) \)
\( \quad -\text{abs}((\text{cor}(\text{data}$\text{x}[\text{xc}], \text{[1, 2L])} - \text{cor}(\text{data}$\text{x}[\text{!xc}, \text{[1, 2L])}) \)

## check
\( \text{OF}(x0, \text{data}) \)

## check
\( \text{OF}(\text{neighbour}(x0, \text{data}), \text{data}) \)

## plot data
\( \text{par(mfrow} = \text{c(1,3), bty} = \text{"h")} \)
\( \text{plot(data}$\text{x,} \)
\( \quad \text{xlim} = \text{c(-3,3), ylim} = \text{c(-3,3),} \)
\( \quad \text{main} = \text{"all data", col} = \text{"darkgreen")} \)

## *Local Search*
\( \text{algo} \leftarrow \text{list(nS} = 3000L, \)
\( \quad \text{neighbour} = \text{neighbour,} \)
testFunctions

Classical Test Functions for Unconstrained Optimisation

description

A number of functions that have been suggested in the literature as benchmarks for unconstrained optimisation.

Usage

<table>
<thead>
<tr>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>tfAckley(x)</td>
</tr>
<tr>
<td>tfEggholder(x)</td>
</tr>
<tr>
<td>tfGriewank(x)</td>
</tr>
<tr>
<td>tfRastrigin(x)</td>
</tr>
<tr>
<td>tfRosenbrock(x)</td>
</tr>
<tr>
<td>tfSchwefel(x)</td>
</tr>
<tr>
<td>tfTrefethen(x)</td>
</tr>
</tbody>
</table>
Arguments

\(x\) a numeric vector of arguments. See Details.

Details

All functions take as argument only one variable, a numeric vector \(x\) whose length determines the dimensionality of the problem.

The Ackley function is implemented as

\[
\exp(1) + 20 - 20 \exp\left(-0.2 \sqrt{\frac{1}{n} \sum_{i=1}^{n} x_i^2}\right) - \exp\left(\frac{1}{n} \sum_{i=1}^{n} \cos(2\pi x_i)\right).
\]

The minimum function value is zero; reached at \(x = 0\).

The Eggholder takes a two-dimensional \(x\), here written as \(x\) and \(y\). It is defined as

\[
-(y+47) \sin\left(\sqrt{|y + \frac{x}{2} + 47|}\right) - x \sin\left(\sqrt{|x - (y+47)|}\right).
\]

The minimum function value is -959.6407; reached at \(c(512, 404.2319)\).

The Griewank function is given by

\[
1 + \frac{1}{4000} \sum_{i=1}^{n} x_i^2 - \prod_{i=1}^{n} \cos\left(\frac{x_i}{\sqrt{i}}\right).
\]

The function is minimised at \(x = 0\); its minimum value is zero.

The Rastrigin function:

\[
10n + \sum_{i=1}^{n} (x_i^2 - 10 \cos(2\pi x_i)).
\]

The minimum function value is zero; reached at \(x = 0\).

The Rosenbrock (or banana) function:

\[
\sum_{i=1}^{n-1} (100(x_{i+1} - x_i^2)^2 + (1 - x_i)^2).
\]

The minimum function value is zero; reached at \(x = 1\).

The Schwefel function:

\[
\sum_{i=1}^{n} \left(-x_i \sin\left(\sqrt{|x_i|}\right)\right).
\]

The minimum function value (to about 8 digits) is \(-418.9829n\); reached at \(x = 420.9687\).

Trefethen’s function takes a two-dimensional \(x\) (here written as \(x\) and \(y\)); it is defined as

\[
\exp(\sin(50x)) + \sin(60e^y) + \sin(70 \sin(x)) + \sin(\sin(80y)) - \sin(10(x + y)) + \frac{1}{4}(x^2 + y^2).
\]

The minimum function value is -3.3069; reached at \(c(-0.0244, 0.2106)\).
Value

The objective function evaluated at \( x \) (a numeric vector of length one).

Warning

These test functions represent artificial problems. It is practically not too helpful to fine-tune a method on such functions. (That would be like memorising all the answers to a particular multiple-choice test.) The functions' main purpose is checking the numerical implementation of algorithms.

Author(s)

Enrico Schumann

References


See Also

DEopt, PSopt

Examples

### persp for two-dimensional \( x \)

```r
## Ackley
n <- 100L; surf <- matrix(NA, n, n)
x1 <- seq(from = -2, to = 2, length.out = n)
for (i in 1:n)
  for (j in 1:n)
    surf[i, j] <- tfAckley(c(x1[i], x1[j]))
persp(x1, x1, -surf, phi = 30, theta = 30, expand = 0.5,
col = "goldenrod1", shade = 0.2, ticktype = "detailed",
xlab = "x1", ylab = "x2", zlab = "-f", main = "Ackley (-f)",
border = NA)
```

```r
## Trefethen
n <- 100L; surf <- matrix(NA, n, n)
x1 <- seq(from = -10, to = 10, length.out = n)
for (i in 1:n)
  for (j in 1:n)
    surf[i, j] <- tfTrefethen(c(x1[i], x1[j]))
persp(x1, x1, -surf, phi = 30, theta = 30, expand = 0.5,
col = "goldenrod1", shade = 0.2, ticktype = "detailed",
xlab = "x1", ylab = "x2", zlab = "-f", main = "Trefethen (-f)",
border = NA)
```
trackingPortfolio  

**Description**

Computes a portfolio similar to a benchmark, e.g. for tracking the benchmark’s performance or identifying factors.

**Usage**

```r
trackingPortfolio(var, wmin = 0, wmax = 1, 
                  method = "qp", objective = "variance", R)
```

**Arguments**

- **var**
  - the covariance matrix: a numeric (real), symmetric matrix. The first asset is the benchmark.
- **R**
  - a matrix of returns: each column holds the returns of one asset; each row holds the returns for one observation. The first asset is the benchmark.
- **wmin**
  - numeric: a lower bound on weights. May also be a vector that holds specific bounds for each asset.
- **wmax**
  - numeric: an upper bound on weights. May also be a vector that holds specific bounds for each asset.
- **method**
  - character. Currently, "qp" and "ls" are supported.
- **objective**
  - character. Currently, "variance" and "sum.of.squares" are supported.

**Details**

With method "qp", the function uses `solve.QP` from package `quadprog`. Because of the algorithm that `solve.QP` uses, `var` has to be positive definite (i.e. must be of full rank).

**Value**

- a numeric vector (the portfolio weights)

**Author(s)**

Enrico Schumann

**References**


vanillaBond

Pricing Plain-Vanilla Bonds

Description

Calculate the theoretical price and yield-to-maturity of a list of cashflows.

Usage

vanillaBond(cf, times, df, yields)
ytm(cf, times, y0 = 0.05, tol = 1e-05, maxit = 1000L, offset = 0)
duration(cf, times, yield, modified = TRUE, raw = FALSE)
convexity(cf, times, yield, raw = FALSE)
Arguments

cf  
Cashflows; a numeric vector or a matrix. If a matrix, cashflows should be arranged in rows; times-to-payment correspond to columns.
times  
times-to-payment; a numeric vector
df  
discount factors; a numeric vector
yields  
onoptional (instead of discount factors); zero yields to compute discount factor; if of length one, a flat zero curve is assumed
yield  
numeric vector of length one (both duration and convexity assume a flat yield curve)
y0  
starting value
tol  
tolerance
maxit  
maximum number of iterations
offset  
numeric: a ‘base’ rate over which to compute the yield to maturity. See Details and Examples.
modified  
logical: return modified duration? (default TRUE)
raw  
logical: default FALSE. Compute duration/convexity as derivative of cashflows’ present value? Use this if you want to approximate the change in the bond price by a Taylor series (see Examples).

Details

devanillaBond computes the present value of a vector of cashflows; it may thus be used to evaluate not just bonds but any instrument that can be reduced to a deterministic set of cashflows.
ytm uses Newton’s method to compute the yield-to-maturity of a bond (a.k.a. internal interest rate). When used with a bond, the initial outlay (i.e. the bonds dirty price) needs be included in the vector of cashflows. For a coupon bond, a good starting value y0 is the coupon divided by the dirty price of the bond.

An offset can be specified either as a single number or as a vector of zero rates. See Examples.

Value

numeric

Author(s)

Enrico Schumann

References


See Also

NS, NSS
Examples

## ytm

cf <- c(5, 5, 5, 5, 5, 105)  ## cashflows
-times <- 1:6  ## maturities
y <- 0.0127  ## the "true" yield
b0 <- vanillaBond(cf, times, yields = y)
cf <- c(-b0, cf); times <- c(0, times)
ytm(cf, times)

## ... with offset

cf <- c(5, 5, 5, 5, 5, 105)  ## cashflows
times <- 1:6  ## maturities
y <- 0.02 + 0.01  ## risk-free 2% + risk-premium 1%
b0 <- vanillaBond(cf, times, yields = y)
cf <- c(-b0, cf); times <- c(0, times)
ytm(cf, times, offset = 0.02)  ## ... only the risk-premium

cf <- c(5, 5, 5, 5, 5, 105)  ## cashflows
times <- 1:6  ## maturities
y <- NS(c(6,9,10,5)/100, times)  ## risk-premium 1%
b0 <- vanillaBond(cf, times, yields = y + 0.01)
cf <- c(-b0, cf); times <- c(0, times)
ytm(cf, times, offset = c(0,y))  ## ... only the risk-premium

## bonds

cf <- c(5, 5, 5, 5, 5, 105)  ## cashflows
times <- 1:6  ## maturities
df <- 1/(1+y)^times  ## discount factors
all.equal(vanillaBond(cf, times, df),
          vanillaBond(cf, times, yields = y))

## ... using Nelson--Siegel

vanillaBond(cf, times, yields = NS(c(0.03,0,0,1), times))

## several bonds

## cashflows are numeric vectors in a list 'cf',
## times-to-payment are numeric vectors in a
## list 'times'

times <- list(1:3,
              1:4,
              0.5 + 0:5)
cf <- list(c(6, 6, 106),
           c(4, 4, 4, 104),
           c(2, 2, 2, 102))

alltimes <- sort(unique(unlist(times)))
M <- array(0, dim = c(length(cf), length(alltimes)))
for (i in seq_along(times))
  M[i, match(times[[i]], alltimes)] <- cf[[i]]
rownames(M) <- paste("bond "., 1:3, sep = ")
colnames(M) <- format(alltimes, nsmall = 1)
vanillaBond(cf = M, times = alltimes, yields = 0.02)

## duration/convexity
cf <- c(5, 5, 5, 5, 5, 105)  ## cashflows
times <- 1:6  ## maturities
y <- 0.0527  ## yield to maturity
d <- 0.001  ## change in yield (+10 bp)
vanillaBond(cf, times, yields = y + d) - vanillaBond(cf, times, yields = y)
duration(cf, times, yield = y, raw = TRUE) * d

duration(cf, times, yield = y, raw = TRUE) * d +
  convexity(cf, times, yield = y, raw = TRUE)/2 * d^2

vanillaOptionEuropean  Pricing Plain-Vanilla Options (European and American)

Description
Functions to calculate the theoretical prices and (some) Greeks for plain vanilla options.

Usage

vanillaOptionEuropean(S, X, tau, r, q, v, tauD = 0, D = 0,
type = "call", greeks = TRUE,
model = NULL, ...)
vanillaOptionAmerican(S, X, tau, r, q, v, tauD = 0, D = 0,
type = "call", greeks = TRUE, M = 101)

vanillaOptionImpliedVol(exercise = "european", price, S, X, tau, r,
  q = 0, tauD = 0, D = 0, type = "call",
  M = 101,
  uniroot.control = list(), uniroot.info = FALSE)

Arguments

S  spot
X  strike
tau  time-to-maturity in years
r  risk-free rate
q  continuous dividend yield, see Details.
v  variance (volatility squared)
tauD  vector of times-to-dividends in years. Only dividends with tauD greater than zero and not greater than tau are kept.
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D vector of dividends (in currency units); default is no dividends.
type call or put; default is call.
greeks compute Greeks? Defaults to TRUE. But see Details for American options.
model what model to use to value the option. Default is NULL which is equivalent to bsm.
... parameters passed to pricing model
M number of time steps in the tree
exercise european (default) or american
price numeric; the observed price to be recovered through choice of volatility.
uniroot.control A list. If there are elements named interval, tol or maxiter, these are passed to uniroot. Any other elements of the list are ignored.
uniroot.info logical; default is FALSE. If TRUE, the function will return the information returned by uniroot. See paragraph Value below.

Details

For European options the formula of Messrs Black, Scholes and Merton is used. It can be used for equities (set q equal to the dividend yield), futures (Black, 1976; set q equal to r), currencies (Garman and Kohlhagen, 1983; set q equal to the foreign risk-free rate). For future-style options (e.g. options on the German Bund future), set q and r equal to zero.

The Greeks are provided in their raw (‘textbook’) form with only one exception: Theta is made negative. For practical use, the other Greeks are also typically adjusted: Theta is often divided by 365 (or some other yearly day count); Vega and Rho are divided by 100 to give the sensitivity for one percentage-point move in volatility/the interest rate. Raw Gamma is not much use if not adjusted for the actual move in the underlier.

For European options the Greeks are computed through the respective analytic expressions. For American options only Delta, Gamma and Theta are computed because they can be directly obtained from the binomial tree; other Greeks need to be computed through a finite difference (see Examples).

For the European-type options, the function understands vectors of inputs, except for dividends. American options are priced via a Cox-Ross-Rubinstein tree; no vectorisation is implemented here.

The implied volatility is computed with uniroot from the stats package (the default search interval is c(0.00001,2); it can be changed through uniroot.control).

Dividends (D) are modelled via the escrowed-dividend model.

Value

Returns the price (a numeric vector of length one) if greeks is FALSE, else returns a list.

Note

If greeks is TRUE, the function will return a list with named elements (value, delta and so on). Prior to version 0.26-3, the first element of this list was named price.
vanillaOptionEuropean

Author(s)
Enrico Schumann

References


See Also
EuropeanCall, callCF

Examples
S <- 100; X <- 100; tau <- 1; r <- 0.02; q <- 0.06; vol <- 0.3
unlist(vanillaOptionEuropean(S, X, tau, r, q, vol^2, type = "put"))

S <- 100; X <- 110; tau <- 1; r <- 0.1; q <- 0.06; vol <- 0.3; type <- "put"
unlist(vanillaOptionAmerican(S, X, tau, r, q, vol^2, type = type,
greeks = TRUE))

## compute rho for 1% move
h <- 0.01
(vanillaOptionAmerican(S, X, tau, r + h, q, vol^2,
  type = type, greeks = FALSE) -
  vanillaOptionAmerican(S, X, tau, r, q, vol^2,
  type = type, greeks = FALSE)) / (h*100)

## compute vega for 1% move
h <- 0.01
(vanillaOptionAmerican(S, X, tau, r, q,(vol + h)^2,
  type = type, greeks = FALSE) -
  vanillaOptionAmerican(S, X, tau, r, q, vol^2,
  type = type, greeks = FALSE)) / (h*100)

S <- 100; X <- 100
tau <- 1; r <- 0.05; q <- 0.00
D <- c(1,2); tauD <- c(0.3,.6)
type <- "put"
v <- 0.245^2 ## variance, not volatility

p <- vanillaOptionEuropean(S = S, X = X, tau, r, q, v = v,
  tauD = tauD, D = D, type = type, greeks = FALSE)
vanillaOptionImpliedVol(exercise = "european", price = p,
  S = S, X = X, tau = tau, r = r, q = q, tauD = tauD, D = D, type = type)
p <- vanillaOptionAmerican(S = S, X = X, tau, r, q, v = v, 
tauD = tauD, D = D, type = type, greeks = FALSE)
vanillaOptionImpliedVol(exercise = "american", price = p, 
S = S, X = X, tau = tau, r = r, q = q, tauD = tauD, D = D, type = type, uniroot.control = list(interval = c(0.01, 0.5)))

## compute implied q
S <- 100; X <- 100
tau <- 1; r <- 0.05; q <- 0.072
v <- 0.22^2  ## variance, not volatility

call <- vanillaOptionEuropean(S=S, X = X, tau=tau, r=r, q=q, v=v, 
type = "call", greeks = FALSE)
put <- vanillaOptionEuropean(S=S, X = X, tau=tau, r=r, q=q, v=v, 
type = "put", greeks = FALSE)

# ... the simple way
-(log(call + X * exp(-tau*r) - put) - log(S)) / tau

# ... the complicated way :-)
volDiffCreate <- function(exercise, call, put, S, X, tau, r) {
  f <- function(q) {
    cc <- vanillaOptionImpliedVol(exercise = exercise, price = call, 
    S = S, X = X, tau = tau, r = r, q = q, type = "call")
    pp <- vanillaOptionImpliedVol(exercise = exercise, price = put, 
    S = S, X = X, tau = tau, r = r, q = q, type = "put")
    abs(cc - pp)
  }
  f
}

f <- volDiffCreate(exercise = "european", 
call = call, put = put, S = S, X = X, tau = tau, r)
optimise(f,interval = c(0, 0.2))$minimum

##
S <- 100; X <- 100
tau <- 1; r <- 0.05; q <- 0.072
v <- 0.22^2  ## variance, not volatility
vol <- 0.22

vanillaOptionEuropean(S=S, X = X, tau=tau, r=r, q=q, v=v, 
    type = "call", greeks = FALSE)

vanillaOptionEuropean(S=S, X = X, tau=tau, r=r, q=q, vol=vol, 
    type = "call", greeks = FALSE)

vanillaOptionEuropean(S=S, X = X, tau=tau, r=r, q=q, vol=vol, 
    type = "call", greeks = FALSE, v = 0.2^2)
Description

Compute the contract value of an Australian government-bond future from its quoted price.

Usage

xtContractValue(quoted.price, coupon, do.round = TRUE)
xtTickValue(quoted.price, coupon, do.round = TRUE)

Arguments

quoted.price The price, as in 99.02.
coupon numeric; should be 6, not 0.06
do.round If TRUE, round as done by ASX clearing house.

Details

Australian government-bond futures, traded at the Australian Securities Exchange (ASX), are quoted as 100 - yield. The function computes the actual contract value from the quoted price.

xtTickValue computes the tick value via a central difference.

Value

A numeric vector.

Author(s)

Enrico Schumann

References


Examples

quoted.price <- 99
coupon <- 6
xtContractValue(quoted.price, coupon)
xtTickValue(quoted.price, coupon)
## convexity
quoted.price <- seq(90, 100, by = 0.1)
plot(100 - quoted.price,
    xtContractValue(quoted.price, coupon),
    xlab = "Yield", ylab = "Contract value")
Description

Compute nodes and weights for Gauss integration.

Usage

\[
\text{xwGauss}(n, \text{method} = \text{"legendre"})
\]
\[
\text{changeInterval}(\text{nodes}, \text{weights}, \text{oldmin}, \text{oldmax}, \text{newmin}, \text{newmax})
\]

Arguments

- \text{n} \quad \text{number of nodes}
- \text{method} \quad \text{character. default is \text{"legendre"}; also possible are \text{"laguerre"} and \text{"hermite"}}
- \text{nodes} \quad \text{the nodes (a numeric vector)}
- \text{weights} \quad \text{the weights (a numeric vector)}
- \text{oldmin} \quad \text{the minimum of the interval (typically as tabulated)}
- \text{oldmax} \quad \text{the maximum of the interval (typically as tabulated)}
- \text{newmin} \quad \text{the desired minimum of the interval}
- \text{newmax} \quad \text{the desired maximum of the interval}

Details

\text{xwGauss} computes nodes and weights for integration for the interval -1 to 1. It uses the method of Golub and Welsch (1969).

\text{changeInterval} is a utility that transforms nodes and weights to an arbitrary interval.

Value

\[
\text{a list with two elements}
\]
\[
\text{weights} \quad \text{a numeric vector}
\]
\[
\text{nodes} \quad \text{a numeric vector}
\]

Author(s)

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References


See Also
callHestoncf

Examples

```r
## examples from Gilli/Maringer/Schumann (2011), ch. 15

## a test function
f1 <- function(x) exp(-x)
m <- 5; a <- 0; b <- 5
h <- (b - a)/m

## rectangular rule -- left
w <- h; k <- 0:(m-1); x <- a + k * h
sum(w * f1(x))

## rectangular rule -- right
w <- h; k <- 1:m; x <- a + k * h
sum(w * f1(x))

## midpoint rule
w <- h; k <- 0:(m-1); x <- a + (k + 0.5)*h
sum(w * f1(x))

## trapezoidal rule
w <- h
k <- 1:(m-1)
x <- c(a, a + k*h, b)
aux <- w * f1(x)
sum(aux) - (aux[1] + aux[length(aux)])/2

## R’s integrate (from package stats)
integrate(f1, lower = a, upper = b)

## Gauss--Legendre
temp <- xwGauss(m)
temp <- changeInterval(temp$nodes, temp$weights,
  oldmin = -1, oldmax = 1, newmin = a, newmax = b)
x <- temp$nodes; w <- temp$weights
sum(w * f1(x))
```

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