Package 'noisyCE2'

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Type Package

Title Cross-Entropy Optimisation of Noisy Functions

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URL https://www.flaviosanti.it/software/noisyCE2

BugReports https://github.com/f-santi/noisyCE2/issues

Description Cross-Entropy optimisation of unconstrained deterministic and noisy functions illustrated in Rubinstein and Kroese (2004, ISBN: 978-1-4419-1940-3) through a highly flexible and customisable function which allows user to define custom variable domains, sampling distributions, updating and smoothing rules, and stopping criteria. Several built-in methods and settings make the package very easy-to-use under standard optimisation problems.

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`noisyCE2-package` *Cross-Entropy Optimisation of Noisy Functions*

Description

The package `noisyCE2` implements the cross-entropy algorithm (Rubinstein and Kroese, 2004) for the optimisation of unconstrained deterministic and noisy functions through a highly flexible and customisable function which allows user to define custom variable domains, sampling distributions, updating and smoothing rules, and stopping criteria. Several built-in methods and settings make the package very easy-to-use under standard optimisation problems.

Details

The package permits a noisy function to be maximised by means of the cross-entropy algorithm. Formally, problems in the form

$$\max_{x \in \Theta} \mathbf{E}(f(x))$$

are tackled for a noisy function $f: \Theta \subseteq \mathbf{R}^m \to \mathbf{R}$.

Author(s)

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References

Bee M., G. Espa, D. Giuliani, F. Santi (2017) "A cross-entropy approach to the estimation of generalised linear multilevel models", *Journal of Computational and Graphical Statistics*, **26** (3), pp. 695-708. https://doi.org/10.1080/10618600.2016.1278003

Rubinstein, R. Y., and Kroese, D. P. (2004), *The Cross-Entropy Method*, Springer, New York. ISBN: 978-1-4419-1940-3

See Also

Useful links:

- https://www.flaviosanti.it/software/noisyCE2
- Report bugs at https://github.com/f-santi/noisyCE2/issues

Examples

```
# EXAMPLE 1
# The negative 4-dimensional paraboloid can be maximised as follows:
negparaboloid <- function(x) { -sum((x - (1:4))^2) }
sol <- noisyCE2(negparaboloid, domain = rep('real', 4))

# EXAMPLE 2
# The 10-dimensional Rosenbrock's function can be minimised as follows:
rosenbrock <- function(x) {
  sum(100 * (tail(x, -1) - head(x, -1)^2)^2 + (head(x, -1) - 1)^2)
}

newvar <- type_real(
  init = c(0, 2),
  smooth = list(
    quote(smooth_lin(x, xt, 1)),
    quote(smooth_dec(x, xt, 0.7, 5))
  )
)

sol <- noisyCE2(
  rosenbrock, domain = rep(list(newvar), 10),
  maximise = FALSE, N = 2000, maxiter = 10000
)

# EXAMPLE 3
# The negative 4-dimensional paraboloid with additive Gaussian noise can be
# maximised as follows:
noisyparaboloid <- function(x) { -sum((x - (1:4))^2) + rnorm(1) }
sol <- noisyCE2(noisyparaboloid, domain = rep('real', 4), stoprule = geweke(x))
# where the stopping criterion based on the Geweke's test has been adopted
# according to Bee et al. (2017).
```

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geweke *Geweke's test stopping rule*

Description

geweke tests the convergence of x through the Geweke's test.

Usage

```
geweke(x, frac1 = 0.3, frac2 = 0.4, pvalue = 0.05)
```

Arguments

x	numeric vector of last γ_n values, as selected by the function passed to noisyCE2() through the argument stopwindow.
frac1, frac2	fraction arguments of the Geweke's test according to coda::geweke.diag().
pvalue	threshold of the p-value which triggers the stop of the algorithm.

Value

A numeric indicating whether the algorithm has converged:

0	the algorithm has converged.
1	the algorithm has not converged.

See Also

Other stopping rules: ts_change()

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noisyCE2 *Cross-Entropy Optimisation of Noisy Functions*

Description

Unconstraint optimisation of noisy functions through the cross-entropy algorithm.

Usage

```
noisyCE2(
  f,
  domain,
  ...,
  rho = 0.05,
  N = 1000,
  smooth = NULL,
  stopwindow = tail(gam, (n > 20) * n/2),
  stoprule = ts_change(x),
  maxiter = 1000,
  maximise = TRUE,
  verbose = "v"
)

## S3 method for class 'noisyCE2'
print(x, ...)

## S3 method for class 'noisyCE2'
summary(object, ...)
```

```
## S3 method for class 'noisyCE2'
plot(x, what = c("x", "gam", "param"), start = NULL, end = NULL, ...)

## S3 method for class 'noisyCE2'
coef(object, ...)
```

Arguments

f	objective function which takes the vector of optimisation variables as first argument.
domain	a list (or other coercible objects) where each component specifies the domain of each variable of the objective function f. The components of the list may be either objects of typevar class (see type_variable) or strings identifying one of type_variable functions (for example "real" for function type_real()). See § Examples.
...	other arguments to be passed to f or to other methods (for print and plot).
rho	parameter ρ of the Cross-Entropy algorithm. This argument may be passed either as a numeric value in $(0, 1)$ or as an unevaluated expression which may include the number of current iteration n, or the argument N.
N	parameter N of the Cross-Entropy algorithm. This argument may be passed either as a positive integer or as an unevaluated expression which may include the number of current iteration n.
smooth	list of unevaluated expressions to be used as smoothing rules for the parameters of the sampling probability distributions of **all variables**. If not NULL, all default or set smoothing rules of all variables will be overwritten. See type_variable for details and examples.
stopwindow	unevaluated expression returning the object to be passed to the stopping rule. Symbol gam permits the time series γ_t to be used (as a numeric vector).
stoprule	stopping rule passed as an unevaluated expression including x as the object returned by evaluation of argument stopwindow. The algorithm is stopped when zero is returned by the evaluation of stoprule. If returned object has attribute mess, this is used as a message. Currently, built-in stopping rules are ts_change() and geweke(), others may be defined by user.
maxiter	maximum number of iteration. When it is reached, algorithm is stopped whether or not the stopping criterion is satisfied. If the maximum number of iteration is reached, the code and the message components of noisyCE object are overwritten.
maximise	if TRUE (default) f is maximised, otherwise a minimisation of f is performed.
verbose	algorithm verbosity (values v, vv and vvv are admitted).
x, object	object of class noisyCE2, as returned by noisyCE2.
what	type of plot should be drawn. If what = "x" (default), values of the variables are plotted as time series; if what = "gam", time series of statistics γ is plotted; if what = "param", time series of parameters of the sampling distributions are plotted.
start, end	first and last value to be plotted. If NULL, all values are plotted.

Value

An object of class noisyCE2 structured as a list with the following components:

f	argument f.
fobj	objective function f where possible arguments passed through argument ... have been substituted. Thus, the value of the objective function maximised by noisyCE in x0 can be computed as fobj(x0). If a minimisation has been performed, fobj returns f with sign inverted.
xopt	numeric vector with solution.
hxopt	matrix of niter rows and length(xopt) columns with values of variables generated by the optimisation algorithm.
param	list of length(xopt) components where time series of parameters (vectors v_t) are stored for each variable as data.frame objects with niter+1 rows (the first rows are the starting values set through function noisyCEcontrol).
gam	vector of values γ_t.
niter	number of iterations.
code	convergence code of the algorithm. Value 0 means that algorithm has converged; other values are defined according to the stopping rule.
convMess	textual message associated to the convergence code (if any).
compTimes	named vector computation times of each phase.

Methods (by generic)

- print: display synthetic information about a noisyCE2 object
- summary: display summary information about a noisyCE2 object
- plot: plot various components of a noisyCE2 object
- coef: get the solution of the optimisation

Examples

```
library(magrittr)
# Optimisation of the 4-dimensional function:
# f(x1,x2,x3,x4)=-(x1-1)^2-(x2-2)^2-(x3-3)^2-(x4-4)^2
sol <- noisyCE2(function(x) -sum((x - (1:4))^2), domain = rep('real', 4))
# Representation of the convergence process:
plot(sol, what = 'x')
plot(sol, what = 'gam')
```

smooth_dec *Decreasing first-order smoothing rule*

Description

Decreasing smoothing rule

$$x_{t+1} := a_t\, x_t + (1 - a_t)\, x_{t-1}$$

where

$$a_t := b \left(1 - \left(1 - \frac{1}{t}\right)^q\right)$$

for some $0.7 \leq b \leq 1$ and some $5 \leq q \leq 10$.

Usage

```
smooth_dec(x, xt, b, qu)
```

Arguments

x	numeric value of the last value of the parameter.
xt	numeric vector of past values of the parameter (time series).
b	smoothing parameter b.
qu	smoothing parameter q.

Value

A numeric vector of updated parameters.

See Also

Other smoothing rules: smooth_lin()

smooth_lin *Linear first-order smoothing rule*

Description

Linear smoothing rule

$$x_{t+1} := a\, x_t + (1 - a)\, x_{t-1}$$

for some $a \in [0, 1]$.

Usage

```
smooth_lin(x, xt, a)
```

Arguments

x	numeric value of the last value of the parameter.
xt	numeric vector of past values of the parameter (time series).
a	smoothing parameter a.

Value

A numeric vector of updated parameters.

See Also

Other smoothing rules: smooth_dec()

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ts_change *Time series change stopping rule*

Description

Deterministic stopping rule based on the last change in the value of γ_n. Changes smaller than tol, or relative changes smaller than reltol stop the algorithm. This criterion is suitable only in case of deterministic objective functions.

Usage

```
ts_change(x, reltol = 1e-04, tol = 1e-12)
```

Arguments

x	numeric vector of last γ_n values, as selected by the function passed to noisyCE2() through the argument stopwindow.
reltol	relative changes smaller than tol stop the algorithm.
tol	changes smaller than tol stop the algorithm.

Value

A numeric indicating whether the algorithm has converged:

0	the algorithm has converged.
1	the algorithm has not converged.

See Also

Other stopping rules: geweke()

type_variable *Functions for defining the types of variables*

Description

All functions permit fully-customised types of variable to be defined. Functions other than type_custom already include standard default values which make the definition of standard variable types easier and quicker.

Usage

```
type_custom(
  type = "custom",
  init = c(0, 10),
  randomXj = function(n, v) {     rnorm(n, v[1], v[2]) },
  x2v = function(x) {     c(mean(x), sd(x)) },
  v2x = function(v) {     v[1] },
  smooth = list(quote(smooth_lin(x, xt, 1)), quote(smooth_dec(x, xt, 0.9, 10))),
  ...
)

type_real(...)

type_positive(...)

type_negative(...)
```

Arguments

type	label for identifying the type of variable. The name is not used internally in any case.
init	numeric vector of starting values of parameters of the sampling distribution.
randomXj	function for randomly generating variable values according to the sampling distribution. The function should take the number of observations to be generated as a first argument, and the vector of parameters as a second argument; a vector of random values should be returned.
x2v	function for updating the parameters of the sampling distribution. *No smoothing is needed.* The function should take a single argument to be used for updating the parameters.
v2x	function for obtaining point values of variable from the parameters of the sampling distribution.
smooth	list of unevaluated expressions of smoothing functions for each parameter of the sampling distribution.
...	further arguments to be included into the typevar object. In case of function for predefined types, it is possible to use ellipsis for overwriting default values (see § Examples).

Value

An object of class `type` and `typevar`, where `type` is the value of the argument `type` passed to `type_custom`, or predefined lables (if not overwritten) in case of other functions.

Examples

```
# Define a new type of real variable where the first parameter of the
# sampling distribution is updated through the median (instead of the
# mean):
type_real(
  type = 'real2',
  x2v = function(x) { c(median(x), sd(x)) }
)

# Define a new type of real variable whith different smoothing
# parameters:
type_real(
  type = 'real3',
  smooth = list(
    quote(smooth_lin(x, xt, 0.8)),
    quote(smooth_dec(x, xt, 0.99, 15))
  )
)
```

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