Package 'SPOT'

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Title Sequential Parameter Optimization Toolbox

Type Package

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Description A set of tools for model-based optimization and tuning of algorithms (hyperparameter tuning respectively hyperparameter optimization). It includes surrogate models, optimizers, and design of experiment approaches. The main interface is spot, which uses sequentially updated surrogate models for the purpose of efficient optimization. The main goal is to ease the burden of objective function evaluations, when a single evaluation requires a significant amount of resources.

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NeedsCompilation no

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SPOT-package *Sequential Parameter Optimization Toolbox*

Description

Sequential Parameter Optimization Toolbox

Details

SPOT uses a combination statistic models and optimization algorithms for the purpose of parameter optimization. Design of Experiment methods are employed to generate an initial set of candidate solutions, which are evaluated with a user-provided objective function. The resulting data is used to fit a model, which in turn is subject to an optimization algorithm, to find the most promising candidate solution(s). These are again evaluated, after which the model is updated with the new results. This sequential procedure of modeling, optimization, and evaluation is iterated until the evaluation budget is exhausted.

Maintainer

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See Also

Main interface function is spot.

buildBO *Bayesian Optimization Model Interface*

Description

Bayesian Optimization Model Interface

Usage

```
buildBO(x, y, control = list())
```

Arguments

x	matrix of input parameters. Rows for each point, columns for each parameter.
y	one column matrix of observations to be modeled.
control	list of control parameters:

`thetaLower` lower boundary for theta, default is `1e-4`

`thetaUpper` upper boundary for theta, default is `1e2`

`algTheta` algorithm used to find theta, default is `L-BFGS-B`

`budgetAlgTheta` budget for the above mentioned algorithm, default is `200`. The value will be multiplied with the length of the model parameter vector to be optimized.

`optimizeP` boolean that specifies whether the exponents (`p`) should be optimized. Else they will be set to two. Default is `FALSE`

`useLambda` whether or not to use the regularization constant lambda (nugget effect). Default is `TRUE`

`lambdaLower` lower boundary for log10lambda, default is `-6`

`lambdaUpper` upper boundary for log10lambda, default is `0`

`startTheta` optional start value for theta optimization, default is `NULL`

`reinterpolate` whether (`TRUE`,default) or not (`FALSE`) reinterpolation should be performed

`target` target values of the prediction, a vector of strings. Each string specifies a value to be predicted, e.g., "y" for mean, "s" for standard deviation, "ei" for expected improvement. See also `predict.kriging`

Value

an object of class `"spotBOModel"`, with a `predict` method and a `print` method. Basically a list, with the options and found parameters for the model which has to be passed to the predictor function:

`x` sample locations

`y` observations at sample locations (see parameters)

`min` min y val

`thetaLower` lower boundary for theta (see parameters)

`thetaUpper` upper boundary for theta (see parameters)

`algTheta` algorithm to find theta (see parameters)

`budgetAlgTheta` budget for the above mentioned algorithm (see parameters)

`lambdaLower` lower boundary for log10lambda, default is `-6`

`lambdaUpper` upper boundary for log10lambda, default is `0`

`dmodeltheta` vector of activity parameters

`dmodellambda` regularization constant (nugget)

`mu` mean mu

`ssq` sigma square

`Psi` matrix large Psi

`Psinv` inverse of Psi

`nevals` number of Likelihood evaluations during MLE

References

Forrester, Alexander I.J.; Sobester, Andras; Keane, Andy J. (2008). Engineering Design via Surrogate Modelling - A Practical Guide. John Wiley & Sons.

Gramacy, R. B. Surrogates. CRC press, 2020.

Jones, D. R., Schonlau, M., and Welch, W. J. Efficient global optimization of expensive black-box functions. Journal of Global Optimization 13, 4 (1998), 455–492.

See Also

predict.spotBOModel

Examples

```
## Reproduction of Gramacy's classic EI illustration with data from Jones et al.
## Generates Fig. 7.6 from the Gramacy book "Surrogates".
x <- c(1, 2, 3, 4, 12)
y <- c(0, -1.75, -2, -0.5, 5)
## Build BO Model
m1 <- buildBO(x = matrix(x, ncol = 1),
 y = matrix(y, ncol=1),
 control = list(target="ei"))
xx <- seq(0, 13, length=1000)
yy <- predict(object = m1, newdata = xx)
m <- which.min(y)
fmin <- y[m]
mue <- matrix(yy$y, ncol = 1)
s2 <- matrix(yy$s, ncol = 1)
ei <- matrix(yy$ei, ncol = 1)
## Plotting the Results (similar to Fig. 7.6 in Gramacy's Surrogate book)
par(mfrow=c(1,2))
plot(x, y, pch=19, xlim=c(0,13), ylim=c(-4,9), main="predictive surface")
lines(xx, mue)
lines(xx, mue + 2*sqrt(s2), col=2, lty=2)
lines(xx, mue - 2*sqrt(s2), col=2, lty=2)
abline(h=fmin, col=3, lty=3)
legend("topleft", c("mean", "95% PI", "fmin"), lty=1:3,   col=1:3, bty="n")
plot(xx, ei, type="l", col="blue", main="EI", xlab="x", ylim=c(0,max(ei)))
```

---

buildCVModel *buildCVModel*

Description

Build a set of models trained on different folds of cross-validated data. Can be used to estimate the uncertainty of a given model type at any point.

Usage

```
buildCVModel(x, y, control = list())
```

Arguments

x	design matrix (sample locations)
y	vector of observations at x
control	(list), with the options for the model building procedure: types a character vector giving the data type of each variable. All but "factor" will be handled as numeric, "factor" (categorical) variables will be subject to the hamming distance. target target values of the prediction, a vector of strings. Each string specifies a value to be predicted, e.g., "y" for mean, "s" for standard deviation. This can also be changed after the model has been built, by manipulating the respective object$target value. uncertaintyEstimator a character vector specifying which uncertaintyEstimator should be used. "s" or the linearlyAdapted uncertrainty "sLinear". Default is "sLinear". modellingFunction the model that shall be fitted to each data fold

Value

set of models (class cvModel)

---

buildEnsembleStack *Ensemble: Stacking*

Description

Generates an ensemble of surrogate models with stacking (stacked generalization).

Usage

```
buildEnsembleStack(x, y, control = list())
```

Arguments

x	design matrix (sample locations), rows for each sample, columns for each variable.
y	vector of observations at x
control	(list), with the options for the model building procedure: modelL1 Function for fitting the L1 model (default: buildLM) which combines the results of the L0 models. modelL1Control List of control parameters for the L1 model (default: list()). modelL0 A list of functions for fitting the L0 models (default: list(buildLM,buildRandomForest,buil modelL0Control List of control lists for each L0 model (default: list(list(),list(),list())).

Value

returns an object of class ensembleStack.

Note

Loosely based on the code by Emanuele Olivetti https://github.com/emanuele/kaggle_pbr/blob/master/blend.py

References

Bartz-Beielstein, Thomas. Stacked Generalization of Surrogate Models-A Practical Approach. Technical Report 5/2016, TH Koeln, Koeln, 2016.

David H Wolpert. Stacked generalization. Neural Networks, 5(2):241-259, January 1992.

See Also

predict.ensembleStack

Examples

```
## Create design points
x <- cbind(runif(20)*15-5,runif(20)*15)
## Compute observations at design points
y <- funBranin(x)
## Create model with default settings
fit <- buildEnsembleStack(x,y)
## Predict new point
predict(fit,cbind(1,2))
## True value at location
funBranin(matrix( c(1,2), 1))
```

---

buildGaussianProcess *Gaussian Process Model Interface*

Description

Gaussian Process Model Interface

Usage

```
buildGaussianProcess(x, y, control = list())
```

Arguments

x	matrix of input parameters. Rows for each point, columns for each parameter.
y	one column matrix of observations to be modeled.
control	list of control parameters. n subset size.

Value

an object of class "spotGaussianProcessModel", with a predict method and a print method.

Examples

```
N <- 200
x <- matrix( seq(from=-1, to = 1, length.out = N), ncol = 1)
y <- funSphere(x)  + rnorm(N, 0, 0.1)
fit <- buildGaussianProcess(x,y)
## Print model parameters
print(fit)
## Predict at new location
xNew <- matrix( c(-0.1, 0.1), ncol = 1)
predict(fit, xNew)
## True value at location
t(funSphere(xNew))
```

---

buildKriging *Build Kriging Model*

Description

This function builds a Kriging model based on code by Forrester et al.. By default exponents (p) are fixed at a value of two, and a nugget (or regularization constant) is used. To correct the uncertainty estimates in case of nugget, re-interpolation is also by default turned on.

Usage

```
buildKriging(x, y, control = list())
```

Arguments

x	design matrix (sample locations)
y	vector of observations at x
control	(list), with the options for the model building procedure. Note: This can also be changed after the model has been built, by manipulating the respective object$target value.
	types a character vector giving the data type of each variable. All but "factor" will be handled as numeric, "factor" (categorical) variables will be subject to the hamming distance.
	thetaLower lower boundary for theta, default is 1e-4
	thetaUpper upper boundary for theta, default is 1e2
	algTheta algorithm used to find theta, default is optimDE.
	budgetAlgTheta budget for the above mentioned algorithm, default is 200. The value will be multiplied with the length of the model parameter vector to be optimized.

optimizeP boolean that specifies whether the exponents (p) should be optimized. Else they will be set to two. Default is FALSE.

useLambda whether or not to use the regularization constant lambda (nugget effect). Default is TRUE.

lambdaLower lower boundary for log10lambda, default is -6

lambdaUpper upper boundary for log10lambda, default is 0

startTheta optional start value for theta optimization, default is NULL

reinterpolate whether (TRUE,default) or not (FALSE) reinterpolation should be performed.

target values of the prediction, a vector of strings. Each string specifies a value to be predicted, e.g., "y" for mean, "s" for standard deviation, "ei" for expected improvement. See also predict.kriging.

Details

The model uses a Gaussian kernel: k(x,z)=exp(-sum(theta_i * |x_i-z_i|^p_i)). By default, p_i = 2. Note that if dimension x_i is a factor variable (see parameter types), Hamming distance will be used instead of |x_i-z_i|.

Value

an object of class kriging. Basically a list, with the options and found parameters for the model which has to be passed to the predictor function:
x sample locations (scaled to values between 0 and 1)
y observations at sample locations (see parameters)
thetaLower lower boundary for theta (see parameters)
thetaUpper upper boundary for theta (see parameters)
algTheta algorithm to find theta (see parameters)
budgetAlgTheta budget for the above mentioned algorithm (see parameters)
optimizeP boolean that specifies whether the exponents (p) were optimized (see parameters)
normalizeymin minimum in normalized space
normalizeymax maximum in normalized space
normalizexmin minimum in input space
normalizexmax maximum in input space
dmodeltheta vector of activity parameters
Theta log_10 vector of activity parameters (i.e. log10(dmodeltheta))
dmodellambda regularization constant (nugget)
Lambda log_10 of regularization constant (nugget) (i.e. log10(dmodellambda))
yonemu Ay-ones*mu
ssq sigma square
mu mean mu
Psi matrix large Psi
Psinv inverse of Psi
nevals number of Likelihood evaluations during MLE

References

Forrester, Alexander I.J.; Sobester, Andras; Keane, Andy J. (2008). Engineering Design via Surrogate Modelling - A Practical Guide. John Wiley & Sons.

See Also

predict.kriging

Examples

```
## Create design points
set.seed(1)
x <- cbind(runif(20)*15-5,runif(20)*15)
y <- funBranin(x)
## Create model with default settings
fit <- buildKriging(x,y,control = list(algTheta=optimLHD))
## Print model parameters
print(fit)
## Predict at new location
predict(fit,cbind(1,2))
## True value at location
funBranin(matrix(c(1,2), 1))
##
## Next Example: Handling factor variables

## create a test function:
braninFunctionFactor <- function (x) {
y <- (x[2]  - 5.1/(4 * pi^2) * (x[1] ^2) + 5/pi * x[1]  - 6)^2 +
10 * (1 - 1/(8 * pi)) * cos(x[1] ) + 10
if(x[3]==1)
y <- y +1
else if(x[3]==2)
y <- y -1
y
}
## create training data
set.seed(1)
x <- cbind(runif(50)*15-5,runif(50)*15,sample(1:3,50,replace=TRUE))
y <- as.matrix(apply(x,1,braninFunctionFactor))
## fit the model (default: assume all variables are numeric)
fitDefault <- buildKriging(x,y,control = list(algTheta=optimDE))
## fit the model (give information about the factor variable)
fitFactor <- buildKriging(x,y,control =
list(algTheta=optimDE,types=c("numeric","numeric","factor")))
## create test data
xtest <- cbind(runif(200)*15-5,runif(200)*15,sample(1:3,200,replace=TRUE))
ytest <- as.matrix(apply(xtest,1,braninFunctionFactor))
## Predict test data with both models, and compute error
ypredDef <- predict(fitDefault,xtest)$y
ypredFact <- predict(fitFactor,xtest)$y
mean((ypredDef-ytest)^2)
mean((ypredFact-ytest)^2)
```

buildKrigingDACE *Build DACE model*

Description

This Kriging meta model is based on DACE (Design and Analysis of Computer Experiments). It allows to choose different regression and correlation models. The optimization of model parameters is by default done with a bounded simplex method from the `nloptr` package.

Usage

```
buildKrigingDACE(x, y, control = list())
```

Arguments

`x`	design matrix (sample locations), rows for each sample, columns for each variable.
`y`	vector of observations at `x`
`control`	(list), with the options for the model building procedure: `startTheta` optional start value for theta optimization, default is `NULL` `algTheta` algorithm used to find theta, default is `optimDE`. `budgetAlgTheta` budget for the above mentioned algorithm, default is `200`. The value will be multiplied with the length of the model parameter vector to be optimized. `nugget` Value for nugget. Default is -1, which means the nugget will be optimized during MLE. Else it can be fixed in a range between 0 and 1. `regr` Regression function to be used: `regpoly0` (default), `regpoly1`, `regpoly2`. Can be a custom user function. `corr` Correlation function to be used: `corrnoisykriging` (default), `corrkriging`, `corrnoisygauss`, `corrgauss`, `correxp`, `correxpg`, `corrlin`, `corrcubic`,`corrspherical`,`corrspline`. Can also be user supplied (if in the right form). `target` target values of the prediction, a vector of strings. Each string specifies a value to be predicted, e.g., "y" for mean, "s" for standard deviation, "ei" for expected improvement. See also `predict.kriging`. This can also be changed after the model has been build, by manipulating the respective `object$target` value.

Value

returns an object of class `dace` with the following elements:

`model`	A list, containing model parameters
`like`	Estimated likelihood value
`theta`	activity parameters theta (vector)
`p`	exponents p (vector)
`lambda`	nugget value (numeric)
`nevals`	Number of iterations during MLE

Author(s)

The authors of the original DACE Matlab toolbox are Hans Bruun Nielsen, Soren Nymand Lophaven and Jacob Sondergaard.
Extension of the Matlab code by Tobias Wagner <wagner@isf.de>.
Porting and adaptation to R and further extensions by Martin Zaefferer <martin.zaefferer@fh-koeln.de>.

References

S.~Lophaven, H.~Nielsen, and J.~Sondergaard. DACE—A Matlab Kriging Toolbox. Technical Report IMM-REP-2002-12, Informatics and Mathematical Modelling, Technical University of Denmark, Copenhagen, Denmark, 2002.

See Also

predict.dace

Examples

```
## Create design points
x <- cbind(runif(20)*15-5,runif(20)*15)
## Compute observations at design points
y <- funSphere(x)
## Create model with default settings
fit <- buildKrigingDACE(x,y)
## Print model parameters
print(fit)
## Create with different regression and correlation functions
fit <- buildKrigingDACE(x,y,control=list(regr=regpoly2,corr=corrspline))
## Print model parameters
print(fit)
```

---

buildLasso *Lasso Model Interface*

Description

The purpose of this function is to provide an interface as required by spot, to enable modeling and model-based optimization with Lasso models.

Usage

```
buildLasso(x, y, control = list())
```

Arguments

x	matrix of input parameters. Rows for each point, columns for each parameter.
y	one column matrix of observations to be modeled.
control	list of control parameters, currently only with parameter formula. The useStep boolean specifies whether the step function is used. The formula is passed to the lm function. Without a formula, a second order model will be built.

Value

an object of class "spotLassoModel", with a predict method and a print method.

Examples

```
## Test-function:
braninFunction <- function (x) {
(x[2]  - 5.1/(4 * pi^2) * (x[1] ^2) + 5/pi * x[1]  - 6)^2 +
10 * (1 - 1/(8 * pi)) * cos(x[1] ) + 10
}
## Create design points
set.seed(1)
x <- cbind(runif(20)*15-5,runif(20)*15)
## Compute observations at design points (for Branin function)
y <- as.matrix(apply(x,1,braninFunction))
## Create model
fit <- buildLasso(x,y,control = list(algTheta=optimLHD))
## Print model parameters
print(fit)
## Predict at new location
predict(fit,cbind(1,2))
## True value at location
braninFunction(c(1,2))
```

---

buildLM *Linear Model Interface*

Description

This is a simple wrapper for the lm function, which fits linear models. The purpose of this function is to provide an interface as required by SPOT, to enable modeling and model-based optimization with linear models. The linear model is build with main effects. Optionally, the model is also subject to the AIC-based stepwise algorithm, using the step function from the stats package.

Usage

```
buildLM(x, y, control = list())
```

Arguments

x	matrix of input parameters. Rows for each point, columns for each parameter.
y	one column matrix of observations to be modeled.
control	list of control parameters, currently only with parameters useStep and formula. The useStep boolean specifies whether the step function is used. The formula is passed to the lm function. Without a formula, a second order model will be built.

Value

an object of class "spotLinearModel", with a predict method and a print method.

Examples

```
## Create design points
set.seed(1)
x <- cbind(runif(20)*15-5,runif(20)*15)
## Compute observations at design points (for Branin function)
y <- funBranin(x)
## Create model
fit <- buildLM(x,y)
## Print model parameters
print(fit)
## Predict at new location
predict(fit,cbind(1,2))
## True value at location
funBranin(cbind(1,2))
```

---

buildLOESS *Build LOESS Model*

Description

Build an interpolation model using the loess function. Essentially a SPOT-style interface to that function.

Usage

```
buildLOESS(x, y, control = list())
```

Arguments

x	design matrix (sample locations), rows for each sample, columns for each variable.
y	vector of observations at x
control	named list, with the options for the model building procedure loess. These will be passed to loess as arguments. Please refrain from setting the formula or data arguments as these will be supplied by the interface, based on x and y.

Value

returns an object of class spotLOESS.

See Also

predict.spotLOESS

Examples

```
## Create a test function: branin
braninFunction <- function (x) {
(x[2]  - 5.1/(4 * pi^2) * (x[1] ^2) + 5/pi * x[1]  - 6)^2 +
10 * (1 - 1/(8 * pi)) * cos(x[1] ) + 10
}
## Create design points
set.seed(1)
x <- cbind(runif(40)*15-5,runif(40)*15)
## Compute observations at design points
y <- as.matrix(apply(x,1,braninFunction))
## Create model with default settings
fit <- buildLOESS(x,y)
fit
## Predict new point
predict(fit,cbind(1,2))
## True value at location
braninFunction(c(1,2))
## Change model control
fit <- buildLOESS(x,y,control=list(parametric=c(TRUE,FALSE)))
fit
```

---

buildPCA *buildPCA*

Description

buildPCA builds principal components of given dataset. It is used inside plotPCA function to build necessary object to perform principal components analysis.

Usage

```
buildPCA(x, control = list())
```

Arguments

x	dataset of parameters to be transformed
control	control list

Value

returns a list with the following elements:
sdev the standard deviations of the principal components (i.e., the square roots of the eigenvalues of the covariance/correlation matrix, though the calculation is actually done with the singular values of the data matrix).
rotation the matrix of variable loadings (i.e., a matrix whose columns contain the eigenvectors).
x transformed matrix.
center, scale the centering and scaling used, or FALSE.

Author(s)

Alpar Gür <alpar.guer@smail.th-koeln.de>

Examples

```
#define objective function

objFun <- function(x) 2*(x[1] - 1)^2 + 5*(x[2] - 3)^2 + (10*x[3] - x[4]/3)

spotConfig <-
list(types = c('numeric', 'numeric', 'numeric', 'numeric'),
funEvals = 15, #budget
noise = TRUE,
seedFun = 1,
replicated = 2,
seedSPOT = 1,
design = designLHD,
model = buildRandomForest, #surrogate model
optimizer = optimLHD, #LHD to optimize model
optimizerControl = list(funEvals=100)) #100 model evals in each step

lower <- c(-20, -20, -20, -20)
upper <- c(20, 20, 20, 20)

res <- spot(x=NULL,
   fun=objFun,
   lower=lower,
   upper=upper,
   control=spotConfig)

resPCA <- buildPCA(res$x)
```

---

buildRandomForest *Random Forest Interface*

Description

This is a simple wrapper for the randomForest function from the randomForest package. The purpose of this function is to provide an interface as required by SPOT, to enable modeling and model-based optimization with random forest.

Usage

```
buildRandomForest(x, y, control = list())
```

Arguments

x	matrix of input parameters. Rows for each point, columns for each parameter.
y	one column matrix of observations to be modeled.
control	list of control parameters, currently not used.

Value

an object of class "spotRandomForest", with a predict method and a print method.

Examples

```
## Test-function:
braninFunction <- function (x) {
(x[2]  - 5.1/(4 * pi^2) * (x[1] ^2) + 5/pi * x[1]  - 6)^2 +
10 * (1 - 1/(8 * pi)) * cos(x[1] ) + 10
}
## Create design points
set.seed(1)
x <- cbind(runif(20)*15-5,runif(20)*15)
## Compute observations at design points (for Branin function)
y <- as.matrix(apply(x,1,braninFunction))
## Create model
fit <- buildRandomForest(x,y)
## Print model parameters
print(fit)
## Predict at new location
predict(fit,cbind(1,2))
## True value at location
braninFunction(c(1,2))
```

---

buildRanger *ranger Interface*

Description

This is a simple wrapper for the ranger function from the ranger package. The purpose of this function is to provide an interface as required by SPOT, to enable modeling and model-based optimization with ranger.

Usage

```
buildRanger(x, y, control = list())
```

Arguments

x	matrix of input parameters. Rows for each point, columns for each parameter.
y	one column matrix of observations to be modeled.
control	list of control parameters. These are all configuration parameters of the ranger function, and will be passed on to it.

Value

an object of class spotRanger, with a predict method and a print method. #'

Examples

```
## Create a simple training data set
testfun <- function (x) x[1]^2
x <- cbind(sort(runif(30)*2-1))
y <- as.matrix(apply(x,1,testfun))
## test data:
xt <- cbind(sort(runif(3000)*2-1))
## Example with default model (standard randomforest)
fit <- buildRanger(x,y)
yt <- predict(fit,data.frame(x=xt))
plot(xt,yt$y,type="l")
points(x,y,col="red",pch=20)
## Example with extra trees, an interpolating model
fit <- buildRanger(x,y,
                   control=list(rangerArguments =
                                list(replace = FALSE,
                                   sample.fraction=1,
                                   min.node.size = 1,
                                   splitrule = "extratrees")))
yt <- predict(fit,data.frame(x=xt))
plot(xt,yt$y,type="l")
points(x,y,col="red",pch=20)
```

buildrsdummy *Build random search dummy model*

Description

This function is used to emulate uniform random search with SPOT. It is a placeholder for the surrogate model and simply returns an empty list, with class "rsdummy".

Usage

```
buildrsdummy(x, y, control)
```

Arguments

x	x (independent variables), not used.
y	y (dependent variable), not used.
control	control, not used.

buildRSM *Build Response Surface Model*

Description

Using the rsm package, this function builds a linear response surface model.

Usage

```
buildRSM(x, y, control = list())
```

Arguments

x	design matrix (sample locations), rows for each sample, columns for each variable.
y	vector of observations at x
control	(list), with the options for the model building procedure:
	mainEffectsOnly Logical, defaults to FALSE. Set to TRUE if a model with main effects only is desired (no interactions, second order effects).
	canonical Logical, defaults to FALSE. If this is TRUE, use the canonical path to descent from saddle points. Else, simply use steepest descent

Value

returns an object of class spotRSM.

See Also

predict.spotRSM

Examples

```
## Create a test function: branin
braninFunction <- function (x) {
(x[2]  - 5.1/(4 * pi^2) * (x[1] ^2) + 5/pi * x[1]  - 6)^2 +
10 * (1 - 1/(8 * pi)) * cos(x[1] ) + 10
}
## Create design points
x <- cbind(runif(20)*15-5,runif(20)*15)
## Compute observations at design points
y <- as.matrix(apply(x,1,braninFunction))
## Create model with default settings
fit <- buildRSM(x,y)
## Predict new point
predict(fit,cbind(1,2))
## True value at location
braninFunction(c(1,2))
## plots
plot(fit)
## path of steepest descent
descentSpotRSM(fit)
```

---

buildTreeModel *buildTreeModel*

Description

Regression Interface This is a simple wrapper for the `rpart` function from the rpart package. The purpose of this function is to provide an interface as required by SPOT, to enable modeling and model-based optimization with regression trees.

Usage

```
buildTreeModel(x, y, control = list())
```

Arguments

`x`	matrix of input parameters. Rows for each point, columns for each parameter.
`y`	one column matrix of observations to be modeled.
`control`	list of control parameters, currently not used.

Value

an object of class `spotTreeModel`, with a `predict` method and a `print` method.

Examples

```
## Create design points
set.seed(1)
x <- cbind(runif(20)*15-5, runif(20)*15)
## Compute observations at design points (for Branin function)
y <- funBranin(x)
## Create model
fit <- buildTreeModel(x,y)
## Print model parameters
print(fit)
## Predict at new location
predict(fit,cbind(1,2))
## True value at location
funBranin(matrix( c(1,2), 1, ))
##
set.seed(123)
x <- seq(-1,1,1e-2)
y0 <- c(-10,10)
sfun0  <- stepfun(0, y0, f = 0)
y <- sfun0(x)
fit <- buildTreeModel(x,y)
# plot(fit)
# plot(x,y, type = "l")
yhat <- predict(fit, newdata = 1)
yhat$y == 10
```

`checkArrival` *checkArrival*

Description

Calculate arrival events for S-Ring.

Usage

```
checkArrival(probNewCustomer)
```

Arguments

`probNewCustomer`	probability of an arrival of a new customer

Value

logical

Examples

```
checkArrival(0.5)
```

checkFeasibilityNlopGnIngres *Check feasibility for NLOPT_GN_ISRES*

Description

Returns TRUE if x does satisfy ineq constraint OR no constraint function is used

Usage

```
checkFeasibilityNlopGnIngres(x, control)
```

Arguments

x	(1 x n)-matrix to be tested
control	Control list for spot and spotLoop. Generated with spotControl.

Value

logical (TRUE if feasible)

code2nat *Transform coded values to natural values*

Description

Input values from the interval from zero to one, i.e., normalized values, are mapped to the interval from a to b.

Usage

```
code2nat(x, a, b)
```

Arguments

x	matrix of m n-dimensional input values from the interval [0;1], i.e, dim(x) = m x n
a	vector of n-dimensional lower bound, i.e., length(a) = n
b	vector of n-dimensional upper bound, i.e., length(b) = n

Examples

```
x <- matrix(runif(10),2)
a <- c(-1,1,2,3,4)
b <- c(1,2,3,4,5)
R <- code2nat(x,a,b)
```

`dataGasSensor` *Gas Sensor Data*

Description

A data set of a Gas Sensor, similar to the one used by Rebolledo et al. 2016. It also contains information of 10 different test/training splits, to enable comparable evaluation procedures.

Usage

```
dataGasSensor
```

Format

A data frame with 280 rows and 20 columns (1 output, 7 input, 2 disturbance, 10 training/test split) :

Y Measured Sensor Output

X1 Sensor Input 1

X2 Sensor Input 2

X3 Sensor Input 3

X4 Sensor Input 4

X5 Sensor Input 5

X6 Sensor Input 6

X7 Sensor Input 7

Batch Disturbance variable, measurement batch

Sensor Disturbance variable, sensor ID

Set1 test/training split, `1` is training data, `2` is test data

Set2 test/training split

Set3 test/training split

Set4 test/training split

Set5 test/training split

Set6 test/training split

Set7 test/training split

Set8 test/training split

Set9 test/training split

Set10 test/training split

Details

Two different modeling tasks are of interest for this data set: `Y~X1+X2+X3+X4+X5+X6+X7+Batch+Sensor` and `X1~Y+X7+Batch+Sensor`.

References

Margarita A. Rebolledo C., Sebastian Krey, Thomas Bartz-Beielstein, Oliver Flasch, Andreas Fischbach and Joerg Stork.
2016.
Modeling and Optimization of a Robust Gas Sensor.
7th International Conference on Bioinspired Optimization Methods and their Applications (BIOMA 2016).

`descentSpotRSM` *Descent RSM model*

Description

Generate steps along the path of steepest descent for a RSM model. This is only intended as a manual tool to use together with `buildRSM`.

Usage

```
descentSpotRSM(object)
```

Arguments

`object`	RSM model (settings and parameters) of class `spotRSM`.

Value

list with

`x` list of points along the path of steepest descent

`y` corresponding predicted values

See Also

`buildRSM`

designLHD *Latin Hypercube Design Generator*

Description

Creates a latin Hypercube Design (LHD) with user-specified dimension and number of design points. LHDs are created repeatedly created at random. For each each LHD, the minimal pair-wise distance between design points is computed. The design with the maximum of that minimal value is chosen.

Usage

```
designLHD(x = NULL, lower, upper, control = list())
```

Arguments

x	optional matrix x, rows for points, columns for dimensions. This can contain one or more points which are part of the design, but specified by the user. These points are added to the design, and are taken into account when calculating the pair-wise distances. They do not count for the design size. E.g., if x has two rows, control$replicates is one and control$size is ten, the returned design will have 12 points (12 rows). The first two rows will be identical to x. Only the remaining ten rows are guaranteed to be a valid LHD.
lower	vector with lower boundary of the design variables (in case of categorical parameters, please map the respective factor to a set of contiguous integers, e.g., with lower = 1 and upper = number of levels)
upper	vector with upper boundary of the design variables (in case of categorical parameters, please map the respective factor to a set of contiguous integers, e.g., with lower = 1 and upper = number of levels)
control	list of controls: size number of design points retries number of retries during design creation types this specifies the data type for each design parameter, as a vector of either "numeric","integer","factor". (here, this only affects rounding) inequalityConstraint inequality constraint function, smaller zero for infeasible points. Used to replace infeasible points with random points. replicates integer for replications of each design point. E.g., if replications is two, every design point will occur twice in the resulting matrix.

Value

matrix design
- design has length(lower) columns and (size + nrow(x))*control$replicates rows. All values should be within lower <= design <= upper

Author(s)

Original code by Christian Lasarczyk, adaptations by Martin Zaefferer

Examples

```
set.seed(1) #set RNG seed to make examples reproducible
design <- designLHD(,1,2) #simple, 1-D case
design
design <- designLHD(,1,2,control=list(replicates=3)) #with replications
design
design <- designLHD(,c(-1,-2,1,0),c(1,4,9,1),
control=list(size=5, retries=100, types=c("numeric","integer","factor","factor")))
design
x <- designLHD(,c(1,-10),c(2,10),control=list(size=5,retries=100))
x2 <- designLHD(x,c(1,-10),c(2,10),control=list(size=5,retries=100))
plot(x2)
points(x, pch=19)
```

---

designUniformRandom *Uniform Design Generator*

Description

Create a simple experimental design based on uniform random sampling.

Usage

```
designUniformRandom(x = NULL, lower, upper, control = list())
```

Arguments

x	optional data.frame x to be part of the design
lower	vector with lower boundary of the design variables (in case of categorical parameters, please map the respective factor to a set of contiguous integers, e.g., with lower = 1 and upper = number of levels)
upper	vector with upper boundary of the design variables (in case of categorical parameters, please map the respective factor to a set of contiguous integers, e.g., with lower = 1 and upper = number of levels)
control	list of controls: size number of design points types this specifies the data type for each design parameter, as a vector of either "numeric","integer","factor". (here, this only affects rounding) replicates integer for replications of each design point. E.g., if replications is two, every design point will occur twice in the resulting matrix.

Value

matrix design
- design has length(lower) columns and (size + nrow(x))*control$replicates rows. All values should be within lower <= design <= upper

Examples

```
set.seed(1) #set RNG seed to make examples reproducible
design <- designUniformRandom(,1,2) #simple, 1-D case
design
design <- designUniformRandom(,1,2,control=list(replicates=3)) #with replications
design
design <- designUniformRandom(,c(-1,-2,1,0),c(1,4,9,1),
control=list(size=5, types=c("numeric","integer","factor","factor")))
design
x <- designUniformRandom(,c(1,-10),c(2,10),control=list(size=5))
x2 <- designUniformRandom(x,c(1,-10),c(2,10),control=list(size=5))
plot(x2)
points(x, pch=19)
```

---

diff0 *diff0*

Description

Calculate differences

Usage

```
diff0(x)
```

Arguments

x	input vector

Details

Input vector length = output vector length

Value

vector of differences

Examples

```
x <- 1:10
diff0(x)
```

doParallel *Parallel execution of code, dependent on the operating system*

Description

mclapply is only supported on linux and macOS. On Windows parlapply should be used. This function switches between both dependent on the operating system of the user.

Usage

```
doParallel(X, FUN, nCores = 2, ...)
```

Arguments

X	vector with arguments to parallelize over
FUN	function that shall be applied to each element of X
nCores	integer. Defines the number of cores.
...	optional arguments to FUN

expectedImprovement *Expected Improvement*

Description

Compute the negative logarithm of the Expected Improvement of a set of candidate solutions. Based on mean and standard deviation of a candidate solution, this estimates the expectation of improvement. Improvement considers the amount by which the best known value (best observed value) is exceeded by the candidates.

Usage

```
expectedImprovement(mean, sd, min)
```

Arguments

mean	vector of predicted means of the candidate solutions.
sd	vector of estimated uncertainties / standard deviations of the candidate solutions.
min	minimal observed value.

Value

a vector with the negative logarithm of the expected improvement values, -log10(EI).

Examples

```
mean <- 1:10 #mean of the candidates
sd <- 10:1 #st. deviation of the candidates
min <- 5 #best known value
EI <- expectedImprovement(mean,sd,min)
EI
```

---

funBard *funBard (No. 14, More No. 8)*

Description

3-dim Bard Test Function

x0 = (1,1,1) f = 8.21487...1e-3 f = 17.4286... at (0.8406..., -infty, -infty)

Usage

```
funBard(x)
```

Arguments

x	matrix of points to evaluate with the function. Rows for points and columns for dimension.

Value

1-column matrix with resulting function values

References

More, J. J., Garbow, B. S., and Hillstrom, K. E. (1981). Testing unconstrained optimization software. *ACM Transactions on Mathematical Software (TOMS)*, *7*(1), 17-41. doi:10.1145/355934.355936

BARD, Y. Comparison of gradient methods for the solution of nonlinear parameter estimation problems SIAM J. Numer. Anal. 7 (1970), 157-186.

Examples

```
x1 <- matrix(c(1,1),1,)
funBard(x1)
```

funBeale *funBeale (No.11, More No. 5)*

Description

2-dim Beale Test Function

Usage

```
funBeale(x)
```

Arguments

x	matrix of points to evaluate with the function. Rows for points and columns for dimension.

Value

1-column matrix with resulting function values

References

Beale, E.M.L. On an interactive method of finding a local minimum of a function of more than one variable. Tech. Rep. No. 25, Statistical Techniques Research Group, Princeton Univ., Princeton, N.J., 1958.

Rosenbrock, H. (1960). An automatic method for finding the greatest or least value of a function. *The Computer Journal*, *3*(3), 175-184. doi:10.1093/comjnl/3.3.175

Examples

```
x1 <- matrix(c(1,1),1,)
funBeale(x1)

res <- spot(,funBeale,c(1,-1),c(5,2),control=list(funEvals=15))
plotModel(res$model)
```

funBox3d *funbox3D (No. 18, More No. 12)*

Description

Box three-dimensional Test Function

Usage

```
funBox3d(x)
```

Arguments

x	matrix of points to evaluate with the function. Rows for points and columns for dimension.

Value

1-column matrix with resulting function values

References

More, J. J., Garbow, B. S., and Hillstrom, K. E. (1981). Testing unconstrained optimization software. *ACM Transactions on Mathematical Software (TOMS)*, *7*(1), 17-41. doi:10.1145/355934.355936

Box three - dimensional, (1966). A comparison of several current optimization methods, and the use of transformations in constrained problems. *The Computer Journal*, *3*(3), 66-77. https://academic.oup.com/comjnl/article/9/1/67/348150

@examples x <- matrix(c(1,10,1),1,) funBox3d(x)

res <- spot(,funBox3d,c(5,15,-5),c(15,5,5),control=list(funEvals=20)) # plotting the graphs plotModel(res$model,which=1:2) plotModel(res$model,which=2:3) plotModel(res$model,which=c(1,3))

---

funBranin *funBranin (No. 1)*

Description

Branin Test Function

Usage

```
funBranin(x)
```

Arguments

x	matrix of points to evaluate with the function. Rows for points and columns for dimension.

Value

1-column matrix with resulting function values

Examples

```
x1 <- matrix(c(-pi, 12.275),1,)
funBranin(x1)
```

funBrownBs *funbrownBs (No. 10, More No. 4)*

Description

2-dim Brown badly scaled Test Function

Usage

```
funBrownBs(x)
```

Arguments

x	matrix of points to evaluate with the function. Rows for points and columns for dimension.

Details

n=2, m=3 x0 = (1,1) f=0 at (1e6, 2e-6)

Value

1-column matrix with resulting function values

References

More, J. J., Garbow, B. S., and Hillstrom, K. E. (1981). Testing unconstrained optimization software. https://www.osti.gov/servlets/purl/6650344

Examples

```
x1 <- matrix(c(1,1),1,)
funBrownBs(x1)

res <- spot(,fun=funBrownBs,c(-10,-10),c(10,10),control=list(funEvals=20))
plotModel(res$model, points = rbind(c(res$xbest[1], res$xbest[2]),c(1.098e-5,9.106)))
```

funCosts *funCosts*

Description

optimWrapper for getCosts

Usage

```
funCosts(x)
```

Arguments

x	vector: weight multiplier sigma and number of elevators ne

Details

Evaluate synthetic cost function that is based on the number of waiting customers and the number elevators

Value

fitness (costs) as matrix

Examples

```
sigma = 1
ne = 10
x <- matrix(c(sigma, ne), 1,)
funCosts(x)
```

funCyclone *Objective function - Cyclone Simulation: Barth/Muschelknautz*

Description

Calculate cyclone collection efficiency. A simple, physics-based optimization problem (potentially bi-objective). See the references [1,2].

Usage

```
funCyclone(
  x,
  deterministic = c(TRUE, TRUE, TRUE),
  cyclone = list(Da = 1.26, H = 2.5, Dt = 0.42, Ht = 0.65, He = 0.6, Be = 0.2),
 fluid = list(Mu = 1.85e-05, Ve = (50/36)/0.12, lambdag = 1/200, Rhop = 2000, Rhof =
    1.2, Croh = 0.05),
  noiseLevel = list(Vp = 0.1, Rhop = 0.05),
  model = "Barth-Muschelknautz",
  intervals = c(0, 2, 4, 6, 8, 10, 15, 20, 30) * 1e-06,
  delta = c(0, 0.02, 0.03, 0.05, 0.1, 0.3, 0.3, 0.2)
)
```

Arguments

x	vector of length at least one and up to six, specifying non-default geometrical parameters in [m]: Da, H, Dt, Ht, He, Be
deterministic	binary vector. First element specifies whether volume flow is deterministic or not. Second element specifies whether particle density is deterministic or not. Third element specifies whether particle diameters are deterministic or not. Default: All are deterministic (TRUE).
cyclone	list of a default cyclone's geometrical parameters: fluid$Da, fluid$H, fluid$Dt, fluid$Ht, fluid$He and fluid$Be
fluid	list of default fluid parameters: fluid$Mu, fluid$Vp, fluid$Rhop, fluid$Rhof and fluid$Croh
noiseLevel	list of noise levels for volume flow (noiseLevel$Vp) and particle density (noiseLevel$Rhop), only used if non-deterministic.
model	type of the model (collection efficiency only): either "Barth-Muschelknautz" or "Mothes"
intervals	vector specifying the particle size interval bounds.
delta	vector of densities in each interval (specified by intervals). Should have one element less than the intervals parameter.

Value

returns a function that calculates the fractional efficiency for the specified diameter, see example.

References

[1] Zaefferer, M.; Breiderhoff, B.; Naujoks, B.; Friese, M.; Stork, J.; Fischbach, A.; Flasch, O.; Bartz-Beielstein, T. Tuning Multi-objective Optimization Algorithms for Cyclone Dust Separators Proceedings of the 2014 Conference on Genetic and Evolutionary Computation, ACM, 2014, 1223-1230

[2] Breiderhoff, B.; Bartz-Beielstein, T.; Naujoks, B.; Zaefferer, M.; Fischbach, A.; Flasch, O.; Friese, M.; Mersmann, O.; Stork, J.; Simulation and Optimization of Cyclone Dust Separators Proceedings 23. Workshop Computational Intelligence, 2013, 177-196

Examples

```
## Call directly
funCyclone(c(1.26,2.5))
## create vectorized target funcion, vectorized, first objective only
## Also: negated, since SPOT always does minimization.
tfunvecF1 <-function(x){-apply(x,1,funCyclone)[1,]}
tfunvecF1(matrix(c(1.26,2.5,1,2),2,2,byrow=TRUE))
## optimize with spot
res <- spot(fun=tfunvecF1,lower=c(1,2),upper=c(2,3),
   control=list(modelControl=list(target="ei"),
   model=buildKriging,optimizer=optimLBFGSB,plots=TRUE))
## best found solution ...
res$xbest
## ... and its objective function value
res$ybest
```

`funError` *funError*

Description

Simulate NAs, Infs, NaNs in results from objective function evaluations

Usage

```
funError(x, prob = 0.1, errorList = list(NA, Inf, NaN), outDim = 1)
```

Arguments

`x`	input vector or matrix of candidate solution
`prob`	error probability (0<prob<1). Default: 0.1
`errorList`	list with error types. Default: `list(NA, Inf, NaN)`
`outDim`	dimension of the output matrix (number of columns)

Details

Results from `funSphere` are replaced with `NA`, `NaN`, and `Inf` values.

Value

vector of objective function values

See Also

`is.finite`

Examples

```
set.seed(123)
require(SPOT)
x <- matrix(1:10, 5,2)
y <- funError(x)
any(is.na(y))
## two-dim output
funError(x,outDim=2)
funError(x,outDim=2, prob=0.1)
```

`funFreudRoth` *funFreudRoth (No. 8, More No. 2)*

Description

2-dim Freudenstein and Roth Test Function

Usage

```
funFreudRoth(x)
```

Arguments

x	matrix of points to evaluate with the function. Rows for points and columns for dimension.

Value

1-column matrix with resulting function values

References

More, J. J., Garbow, B. S., and Hillstrom, K. E. (1981). Testing unconstrained optimization software. *ACM Transactions on Mathematical Software (TOMS)*, *7*(1), 17-41. doi:10.1145/355934.355936

B. Freudenstein, F., and Roth, B. (Oct. 1963). Numerical solutions of systems of nonlinear equations. *The ACM Journal*, *3*(3), 550-556. https://dl.acm.org/doi/10.1145/321186.321200

Examples

```
x1 <- matrix(c(1,1),1,)
funFreudRoth(x1)

# Running SPOT with 20 function evaluations with default configurations
res <- spot(,funFreudRoth,c(0,0),c(10,10),control=list(funEvals=20))
plotModel(res$model)
```

funGauss *funGauss (No. 15, More No. 9)*

Description

3-dim Gaussian Test Function

Usage

```
funGauss(x)
```

Arguments

x	matrix of points to evaluate with the function. Rows for points and columns for dimension.

Value

1-column matrix with resulting function values

References

Unpublished

Examples

```
x1 <- matrix(c(1,1,1),1,)
funGauss(x1)

res1 <- spot(,funGauss,
  c(-0.001,-0.007,-0.003),
  c(0.5,1.0,1.1),
  control=list(funEvals=15))
  plotModel(res1$model, which = 1:2)
```

funGoldsteinPrice *Goldstein-Price Test Function (No. 5)*

Description

An implementation of Booker et al.'s method on a re-scaled/coded version of the 2-dim Goldstein–Price function

Usage

```
funGoldsteinPrice(x)
```

Arguments

x	(m, 2)-matrix of points to evaluate with the function. Rows for points and columns for dimension.

Value

1-column matrix with resulting function values

Examples

```
x1 <- matrix(c(-pi, 12.275),1,)
funGoldsteinPrice(x1)
```

---

funGulf *funGulf (No.17, More No. 11)*

Description

3-dim Gulf research and development Test Function

Usage

```
funGulf(x, m = 99)
```

Arguments

x	matrix (n x 3) of points to evaluate with the function. Rows for points and columns for dimension. Values should be larger than 0.
m	additional parameter: . The Gulf function supports an additional parameter m in the range from 3 to 100

Value

1-column matrix with resulting function values

References

More, J. J., Garbow, B. S., and Hillstrom, K. E. (1981). Testing unconstrained optimization software. *ACM Transactions on Mathematical Software (TOMS)*, *7*(1), 17-41. doi:10.1145/355934.355936

Examples

```
x1 <- matrix(c(50,25,1.5),1,)
funGulf(x1)

funGulf(x1,m=50)

resGulf <- spot(,funGulf,c(0,0,0),c(100,50,5))
resGulf$xbest
resGulf$ybest
plotModel(resGulf$model, which=1:2)
plotModel(resGulf$model, which=2:3)

# x0 is an optional start point (or set of start points), specified as a matrix.
# One row for each point, and one column for each optimized parameter.
x0 = matrix(c(5,2.5,0.15),1,3)
resGulf <- spot(x0,funGulf,c(0,0,0),c(100,50,5))
resGulf$xbest
resGulf$ybest
```

`funHelical` *funHelical (No. 13, More No. 7)*

Description

3-dim Helical Test Function

Usage

```
funHelical(x)
```

Arguments

x	matrix (n x 3)-dim of points to evaluate with the function. Rows for points and columns for dimension.

Value

1-column matrix with resulting function values

References

More', J. J., Garbow, B. S., and Hillstrom, K. E. (1981). Testing unconstrained optimization software. *ACM Transactions on Mathematical Software (TOMS)*, *7*(1), 17-41. doi:10.1145/355934.355936

Fletcher, R., and Powell, M. J. (1963). A rapidly convergent descent method for minimization. *The Computer Journal*, *6*(2), 163-168. doi:10.1093/comjnl/6.2.163

Examples

```
x1 <- matrix(c(1,1,1),1,)
funHelical(x1)
res <- spot(,funHelical,c(-40,-40,-40),c(40,40,40),control=list(funEvals=20))
plotModel(res$model,which=c(1,2),type="persp",border="NA")
plotModel(res$model,which=c(2,3),type="persp",border="NA")
plotModel(res$model,which=c(1,3),type="persp",border="NA")
plotModel(res$model, which=c(1,2))
plotModel(res$model, which=c(1,3))
plotModel(res$model, which=c(2,3))
```

`funIshigami` *Ishigami Test Function (No. 7)*

Description

An implementation of the 3-dim Ishigami function.

f(x) = sin(x_1) + a sin^2(x_2) + b x_3^4sin(x_1)

The Ishigami function of Ishigami & Homma (1990) is used as an example for uncertainty and sensitivity analysis methods, because it exhibits strong nonlinearity and nonmonotonicity. It also has a peculiar dependence on x_3, as described by Sobol' & Levitan (1999). The independent distributions of the input random variables are usually: x_i ~ Uniform[-pi, pi], for all i = 1, 2, 3.

Usage

```
funIshigami(x, a = 7, b = 0.1)
```

Arguments

`x`	(`m`,`3`)-matrix of points to evaluate with the function. Values should be >= -pi and <= pi, i.e., x_i in [-pi,pi].
`a`	coefficient (optional), with default value 7
`b`	coefficient (optional), with default value 0.1

Value

1-column matrix with resulting function values

References

Ishigami, T., & Homma, T. (1990, December). An importance quantification technique in uncertainty analysis for computer models. In Uncertainty Modeling and Analysis, 1990. Proceedings., First International Symposium on (pp. 398-403). IEEE.

Sobol', I. M., & Levitan, Y. L. (1999). On the use of variance reducing multipliers in Monte Carlo computations of a global sensitivity index. Computer Physics Communications, 117(1), 52-61.

Examples

```
x1 <- matrix(c(-pi, 0, pi),1,)
funIshigami(x1)
```

`funJennSamp` *funJennSamp (No. 12, More No 6)*

Description

2-dim Jennrich and Sampson Function Test Function

Usage

```
funJennSamp(x)
```

Arguments

x	matrix of points to evaluate with the function. Rows for points and columns for dimension.

Value

1-column matrix with resulting function values

References

More, J. J., Garbow, B. S., & Hillstrom, K. E. (1981). Testing unconstrained optimization software. *ACM Transactions on Mathematical Software (TOMS)*, *7*(1), 17-41. doi:10.1145/355934.355936

Jennrich, R.I., and Sampson (1968). Application of stepwise regression to nonlinear estimation. *Technometrics*, *3*(3), 63-72. https://www.tandfonline.com/doi/abs/10.1080/00401706.1968.10490535

Examples

```
x1 <- matrix(c(1,1),1,)
funJennSamp(x1)

res <- spot(,funJennSamp,c(0,0),c(0.3,0.3))
plotModel(res$model)
```

funMeyer *funMeyer (No. 16, More No. 10)*

Description

Meyer 3-dim Test Function

Usage

```
funMeyer(x)
```

Arguments

x	matrix (dim 1x3) of points to evaluate with the function. Rows for points and columns for dimension.

Value

1-column matrix with resulting function values

References

More, J. J., Garbow, B. S., and Hillstrom, K. E. (1981). Testing unconstrained optimization software. *ACM Transactions on Mathematical Software (TOMS)*, *7*(1), 17-41. doi:10.1145/355934.355936

Examples

```
x1 <- matrix(c(1,1,1),1,)
funMeyer(x1)

set.seed(13)
resMeyer <- spot(matrix(c(0.02,4000,250),1,3),
  funMeyer,c(0,1000,200),c(3,8000,500),
  control= list(funEvals=15))
resMeyer$xbest
resMeyer$ybest
print("Model with parameters")
plotModel(resMeyer$model)
plotModel(resMeyer$model,which=2:3)
```

funMoo *funMoo*

Description

Multi-objective Test Function

Usage

```
funMoo(x)
```

Arguments

x	matrix of points to evaluate with the function. Rows for points and columns for dimension.

Details

funMultiObjectiveOptimization

A multiobjective dummy testfunction

Value

n-column matrix with resulting function values

Examples

```
x1 <- matrix(c(-pi, 12.275),1,)
funMoo(x1)
x <- matrix(c(1,1,2), ncol=3 )
```

funNoise *funNoise*

Description

noise function

Usage

```
funNoise(x, fun = funSphere, mean = 0, sigma = 1)
```

Arguments

x	input matrix of candidate solution
fun	objective function. Default: funSphere
mean	error mean. Default: 1
sigma	error sd. Default: 1

Value

vector of noisy objective function values

Examples

```
set.seed(123)
require(SPOT)
x <- matrix(1:10, 5,2)
funNoise(x)
```

---

funOptimLecture *funOptimLecture*

Description

A testfunction used in the optimizaton lecture of the AIT Masters course at TH Koeln

Usage

```
funOptimLecture(vec)
```

Arguments

vec	input vector or matrix of candidate solution

Value

vector of objective function values

funPowellBs *funPowellBs (No. 9, More No. 3)*

Description

2-dim Powell Badly Scaled Test Function

Usage

```
funPowellBs(x)
```

Arguments

x	matrix of points to evaluate with the function. Rows for points and columns for dimension.

Value

1-column matrix with resulting function values

References

More, J. J., Garbow, B. S., and Hillstrom, K. E. (1981). Testing unconstrained optimization software. *ACM Transactions on Mathematical Software (TOMS)*, *7*(1), 17-41. doi:10.1145/355934.355936

Powell, M.J.D. (1970). A hybrid method for nonlinear equations. In Numerical methods for Nonlinear Algebraic Equations, P. Rabinowitz (Ed), *Gordon & Breach, New York.*, *3*(3), 87-114.

Examples

```
x1 <- matrix(c(-1,1),1,)
funPowellBs(x1)

# Running SPOT with 20 function evaluations with default configurations
res <- spot(,fun=funPowellBs,c(-10,-10),c(10,10),control=list(funEvals=20))
plotModel(res$model, points = rbind(c(res$xbest[1], res$xbest[2]),c(1.098e-5,9.106)))
```

funPowellS *funPowellS (No. 19, More No. 13)*

Description

Powells 4-dim Test Function

Usage

```
funPowellS(x)
```

Arguments

x	matrix (dim 1x4) of points to evaluate with the function. Rows for points and columns for dimension.

Value

1-column matrix with resulting function values

References

More, J. J., Garbow, B. S., and Hillstrom, K. E. (1981). Testing unconstrained optimization software. Trond Steihaug and Sara Suleiman Global convergence and the Powell singular function *ACM Transactions on Mathematical Software (TOMS)*, *7*(1), 17-41. doi:10.1145/355934.355936 http://owos.gm.fh-koeln.de:8055/bartz/optimization-ait-master-2020/blob/master/Jupyter.d/Exercise-VIIa.ipynb http://bab10.bartzandbartz.de:8033/bartzbeielstein/bab-optimization-ait-master-/blob/master/Jupyter.d/01spotNutshell.ipynb https://www.mat.univie.ac.at/~neum/glopt/bounds.html

Powells Test function, M. J. D. Powell, 1962 An automatic method for finding the local minimum of a function. *The Computer Journal*, *3*(3), 175-184. https://www.sfu.ca/~ssurjano/powell.html

Examples

```
x1 <- matrix(c(0,0,0,0),1,)
funPowellS(x1)
x2 <- matrix(c(3,-1,0,1),1,)
funPowellS(x2)
x3 <- matrix(c(0,0,0,-2),1,)
funPowellS(x3)
# optimization run with SPOT and 15 evaluations
res_fun <- spot(,funPowellS,c(-4,-4,-4,-4 ),c(5,5,5,5),control=list(funEvals=15))
res_fun
```

---

funRosen *funRosen (No. 2, More No. 1)*

Description

Rosenbrock Test Function

Usage

```
funRosen(x)
```

Arguments

x	matrix of points to evaluate with the function. Rows for points and columns for dimension.

Value

1-column matrix with resulting function values

References

More, J. J., Garbow, B. S., and Hillstrom, K. E. (1981). Testing unconstrained optimization software. *ACM Transactions on Mathematical Software (TOMS)*, *7*(1), 17-41. doi:10.1145/355934.355936

Rosenbrock, H. (1960). An automatic method for finding the greatest or least value of a function. *The Computer Journal*, *3*(3), 175-184. doi:10.1093/comjnl/3.3.175

Examples

```
x1 <- matrix(c(1,1),1,)
funRosen(x1)
```

`funRosen2` *funRosen2 (No. 2a)*

Description

Rosenbrock Test Function (2-dim)

Usage

```
funRosen2(x)
```

Arguments

`x`	matrix of points to evaluate with the function. Rows for points and columns for dimension.

Value

1-column matrix with resulting function values

Examples

```
x1 <- matrix(c(-pi, 12.275),1,)
funRosen2(x1)
```

funShiftedSphere *funShiftedSphere (No. 4)*

Description

Shifted Sphere Test Function with optimum at x_opt = a and f(x_opt) = 0

Usage

```
funShiftedSphere(x, a = 1)
```

Arguments

x	matrix of points to evaluate with the function. Rows for points and columns for dimension.
a	offset added, i.e., f = sum (x-a)^2. Default: 1.

Value

1-column matrix with resulting function values

See Also

funSphere

Examples

```
x1 <- matrix(c(-pi, 12.275),1,)
a <- 1
funShiftedSphere(x1, a)
```

funSoblev99 *Sobol and Levitan Test Function (No. 6)*

Description

An implementation of the Sobol-Levitan function.

f(x) = exp(sum b_i x_i) - I_d + c_0, where I_d = prod((exp(b_i) -1) / b_i)

The value of the elements in the b-vector (b1, ..., bd) affect the importance of the corresponding x-variables. Sobol' & Levitan (1999) use two different b-vectors: (1.5, 0.9, 0.9, 0.9, 0.9, 0.9), for d = 6, and (0.6, 0.6, 0.6, 0.6, 0.6, 0.6, 0.6, 0.6, 0.6, 0.6, 0.4, 0.4, 0.4, 0.4, 0.4, 0.4, 0.4, 0.4, 0.4, 0.4), for d = 20. Our implementation uses the default b vector: b = c(0.6, 0.6, 0.6, 0.6, 0.6, 0.6, 0.6, 0.6, 0.6, 0.6, 0.4, 0.4, 0.4, 0.4, 0.4, 0.4, 0.4, 0.4, 0.4, 0.4) (when d<=20).

Moon et al. (2012) scale the output to have a variance of 100. For d = 20, they use three different b-vectors: (2, 1.95, 1.9, 1.85, 1.8, 1.75, 1.7, 1.65, 0.4228, 0.3077, 0.2169, 0.1471, 0.0951, 0.0577, 0.0323, 0.0161, 0.0068, 0.0021, 0.0004, 0), (1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0), and (2.6795, 2.2289, 1.8351, 1.4938, 1.2004, 0.9507, 0.7406, 0.5659, 0.4228, 0.3077, 0.2169, 0.1471, 0.0951, 0.0577, 0.0323, 0.0161, 0.0068, 0.0021, 0.0004, 0).

The generally used value of c0 is c0 = 0. The function is evaluated on xi in [0, 1], for all i = 1, ..., d.

Usage

```
funSoblev99(x, b = c(rep(0.6, 10), rep(0.4, 10)), c0 = 0)
```

Arguments

x	(m, 2)-matrix of points to evaluate with the function. Values should be >= 0 and <= 1, i.e., x_i in [0,1].
b	d-dimensional vector (optional), with default value b = c(0.6, 0.6, 0.6, 0.6, 0.6, 0.6, 0.6, 0.6, 0.6, 0.6, 0.4, 0.4, 0.4, 0.4, 0.4, 0.4, 0.4, 0.4, 0.4, 0.4) (when d<=20)
c0	constant term (optional), with default value 0

Value

1-column matrix with resulting function values

References

Moon, H., Dean, A. M., & Santner, T. J. (2012). Two-stage sensitivity-based group screening in computer experiments. Technometrics, 54(4), 376-387.

Sobol', I. M., & Levitan, Y. L. (1999). On the use of variance reducing multipliers in Monte Carlo computations of a global sensitivity index. Computer Physics Communications, 117(1), 52-61.

Examples

```
x1 <- matrix(c(-pi, 12.275),1,)
funSoblev99(x1)
```

---

funSphere *funSphere (No. 3)*

Description

Sphere Test Function

Usage

```
funSphere(x)
```

Arguments

x	matrix of points to evaluate with the function. Rows for points and columns for dimension.

Value

1-column matrix with resulting function values

See Also

funShiftedSphere

Examples

```
x1 <- matrix(c(-pi, 12.275),1,)
funSphere(x1)
```

---

funSring *funSring*

Description

wrapper for sring

Usage

```
funSring(x, opt = list(), ...)
```

Arguments

x	perceptron weights
opt	list of optional parameters, e.g.,
	nElevators number of elevators
	probNewCustomer probability pf a customer arrival
	nIterations Number of itertions
	randomSeed random seed
...	additional parameters

Value

fitness (matrix with one column)

Examples

```
set.seed(123)
numberStates = 200
sigma = 1
x = matrix( rnorm(n = 2*numberStates, 1, sigma), 1,)
funSring(x)
```

`getCosts` *getCosts*

Description

Evaluate synthetic cost function that is based on the number of waiting customers and the number elevators

Usage

```
getCosts(x, ...)
```

Arguments

`x`	vector with `sigma` weight multiplier and `ne` number of elevators
`...`	optional parameters passed to `funSring`

Details

Note: To accelerate testing, nIterations was set to 1e3 (instead of 1e6)

Value

fitness (costs)

Examples

```
set.seed(123)
sigma = 1
ne = 10
x <- c(sigma, ne)
getCosts(x)
```

getMultiStartPoints *Get Multi Start Points*

Description

Determine multi start points for optimization on the surrogate. Combines the current best with additional random starting points for optimization on the surrogate.

Usage

```
getMultiStartPoints(x, y, control)
```

Arguments

x	matrix of design points
y	matrix of function values (f(x))
control	Control list for spot and spotLoop. Generated with spotControl.

Value

x0 matrix of restart points

getNatDesignFromCoded *Get natural parameter values from coded +-1 representation*

Description

For given lower and upper bounds, a and b, respectively, coded input values are mapped to their natural values

Usage

```
getNatDesignFromCoded(x, a, b)
```

Arguments

x	(n,m)-dim matrix of coded values, i.e., lower values are coded as -1, upper values as +1.
a	m-dim vector of lower bounds (natural values)
b	m-dim vector of upper bounds (natural values)

Examples

```
x <- matrix(rep(-1,2),1,)
lower <- c(-10,-10)
upper <- c(10,10)
getNatDesignFromCoded(x, a = lower, b=upper)
```

getPerformanceStats *get performance stats*

Description

determines mean performance

Usage

```
getPerformanceStats(x, y)
```

Arguments

x	matrix of n solutions (usually a (nxd)-matrix, where d is the problem dimension)
y	matrix with objective values (usually a (nx1)-matrix

Details

further stats will be added

Examples

```
x <- matrix(1:10, ncol=2, byrow=TRUE)
y1 <- funSphere(x) +1
y2 <- funSphere(x) -1
x <- rbind(x,x)
y <- rbind(y1, y2)
M <- getPerformanceStats(x,y)
```

getPositions *get impute positions*

Description

Determines positions in a vectors that fulfill criteria defined by a list of criteria, e.g., `is.na`.

Usage

```
getPositions(y, imputeCriteriaFuns = list(is.na, is.infinite, is.nan))
```

Arguments

y	The vector of numerics from which NA/Inf values should be removed
imputeCriteriaFuns	`list` criteria functions specified via `imputeCriteriaFuns` in `spotControl`. Default: `list(is.na, is.infinite, is.nan)`.

Value

p vector of positions that fulfill one of the criteria

Examples

```
imputeCriteriaFuns <- list(is.na, is.infinite, is.nan)
y <- c(1,2,Inf,4,NA,6)
p <- getPositions(y, imputeCriteriaFuns)
```

---

getPower *getPower*

Description

Implements basic power calculations in R See also: https://www.cyclismo.org/tutorial/R/power.html

Usage

```
getPower(mu0, mu1, n, sigma, alpha, tdist = FALSE, alternative = "greater")
```

Arguments

mu0	mean value of the null hypothesis (usually referred to as H0)
mu1	mean value of the alternative hypothesis (usually referred to as H1)
n	sample size
sigma	sample s.d.
alpha	error
tdist	logical. Use Student t Distribution. Default: FALSE
alternative	a character string specifying the alternative hypothesis, must be one of "two.sided", "greater" (default) or "less".

Examples

```
## Power should be approx. 0.9183621:
getPower(mu0=5, mu1=6.5, n=20, sigma=2, alpha=0.05, tdist = FALSE,
alternative = "two.sided")
## Power should be approx. 0.8887417:
getPower(mu0=5, mu1=6.5, n=20, sigma=2, alpha=0.05, tdist = TRUE,
alternative = "two.sided")
## Compare with results from power.t.test
powerVal <- power.t.test(n=20, delta=1.5, sd=2, sig.level=0.05, type="one.sample",
alternative="two.sided",strict = TRUE)
powerVal$power
```

getReplicates *get number of replicates*

Description

determine how often appears x in X

Usage

```
getReplicates(x, X)
```

Arguments

x	row vector
X	matrix

Details

can be used to determine the number of replicates/repeated evaluations of a solution x

Examples

```
k <- 2
n <- 4
A <- matrix(1:(k*n),n,k, byrow = TRUE)
X <- rbind(A,A,A)
x <- A[1,]
## should be 3:
getReplicates(x,X)

## U has unique entries
U <- X[!duplicated(X), ]
## should be 1:
getReplicates(x,U)
```

getSampleSize *getSampleSize*

Description

Implements sample size calculations in R See also: https://www.cyclismo.org/tutorial/R/power.html and https://influentialpoints.com/Training/statistical_power_and_sample_size.htm

Usage

```
getSampleSize(mu0, mu1, alpha, beta, sigma, alternative = "greater")
```

Arguments

mu0	mean value of the null hypothesis (usually referred to as H0)
mu1	mean value of the alternative hypothesis (usually referred to as H1)
alpha	type I error
beta	type II error
sigma	sample s.d.
alternative	a character string specifying the alternative hypothesis, must be one of "two.sided", "greater" (default) or "less".

Value

n number of required samples in each arm of a trial. Note: total number of samples is 2*n.

Examples

```
getSampleSize(mu0 = 0, mu1 = 200, alpha=0.05, beta=0.2, sigma=450,
alternative="two.sided")
getSampleSize(mu0 = 8.72, mu1 = 8.72*1.1, alpha=0.05, beta=0.2, sigma=1.3825,
alternative="greater")
getSampleSize(mu0 = 8.72, mu1 = 8.72*1.1, alpha=0.05, beta=0.2, sigma=1.3825,
alternative="two.sided")
```

---

handleNAsKrigingWorst *handleNAsKrigingWorst*

Description

Remove NAs from a vector by replacing them with a penalized Kriging-based expectation

Usage

```
handleNAsKrigingWorst(
  x,
  y,
  penaltyImputation = 3,
  imputeCriteriaFuns = list(is.na, is.infinite, is.nan)
)
```

Arguments

x	The x values from which y was calculated
y	The vector of numerics from which the NAs should be removed
penaltyImputation	multiplier for sPredicted (penalty term). Default: 3.
imputeCriteriaFuns	list criteria functions specified via imputeCriteriaFuns in spotControl. Default: list(is.na, is.infinite, is.nan).

Value

y The imputed vector w/o NA and w/o Inf values.

Examples

```
imputeCriteriaFuns <- list(is.na, is.infinite, is.nan)
x <- matrix(runif(20), ncol = 2)
y <- funSphere(x)
y[3] <- NA
y[5] <- Inf
plot(y, type="b")
print(y)
y1 <- handleNAsKrigingWorst(x=x, y=y, imputeCriteriaFuns=imputeCriteriaFuns)
print(y1)
points(3, y1[3], type="b", col="red")
points(5, y1[5], type="b", col="red")
```

---

handleNAsMax *handleNAsMax*

Description

Remove NAs from a vector by replacing them by the current max + p*s.d., where p denotes a penalty term.

Usage

```
handleNAsMax(
  x,
  y = NULL,
  imputeCriteriaFuns = list(is.na, is.infinite, is.nan),
  penaltyImputation = 3
)
```

Arguments

x	The x values from which y was calculated, not used here
y	The vector of numerics from which the NAs should be removed
imputeCriteriaFuns	list criteria functions specified via imputeCriteriaFuns in spotControl. Default: list(is.na, is.infinite, is.nan).
penaltyImputation	penalty used for imputed values

Value

y The cleaned vector

Examples

```
vecWithNAs <- c(-1, 0,1,NA,3,Inf,5,NA)
control <- spotControl(dim=length(vecWithNAs))
print(vecWithNAs)
print(handleNAsMax(y=vecWithNAs,
                   imputeCriteriaFuns= control$yImputation$imputeCriteriaFuns))
```

---

handleNAsMean *handleNAsMean*

Description

Remove NAs from a vector by replacing them by the sample mean.

Usage

```
handleNAsMean(
  x,
  y = NULL,
  imputeCriteriaFuns = list(is.na, is.infinite, is.nan),
  penaltyImputation = 3
)
```

Arguments

x	The x values from which y was calculated, not used here
y	The vector of numerics from which the NAs should be removed
imputeCriteriaFuns	list criteria functions specified via imputeCriteriaFuns in spotControl. Default: list(is.na, is.infinite, is.nan).
penaltyImputation	penalty used for imputed values

Value

y The cleaned vector

Examples

```
vecWithNAs <- c(-1, 0,1,NA,3,Inf,5,NA)
control <- spotControl(dim=length(vecWithNAs))
print(vecWithNAs)
print(handleNAsMean(y=vecWithNAs,
                    imputeCriteriaFuns= control$yImputation$imputeCriteriaFuns))
```

`imputeY` *Impute NAs and Inf in y*

Description

Impute NAs and Inf in y

Usage

```
imputeY(x, y, control)
```

Arguments

`x`	The x values from which y was calculated
`y`	The vector of numerics from which NA/Inf values should be removed
`control`	`spot` control list. See also `spotControl`.

Value

y The imputed vector w/o `NA` and w/o `Inf` values.

Examples

```
x <- matrix(runif(10), ncol=2, nrow=5)
y <- funSphere(x)
y[1] <- NA
control <- spotControl(dimension = 2)
# no imputation function, i.e, w/o imputation
imputeY(x=x, y=y, control=control)
# with imputation
control$yImputation$handleNAsMethod <- handleNAsKrigingWorst
y <- imputeY(x=x, y=y, control=control)
# no imputation required:
imputeY(x=x, y=y, control=control)
```

infillEI *Expected Improvement Infill Criterion*

Description

Compute the negative of the Expected Improvement of a set of candidate solutions. Based on mean and standard deviation of a candidate solution, this estimates the expectation of improvement. Improvement considers the amount by which the best known value (best observed value) is exceeded by the candidates. Expected Improvement infill criterion that can be passed to control$modelControl$infillCriterion in order to be used during the optimization in SPOT. Parameters dont have to be specified as this function is ment to be internally by SPOT.

Usage

```
infillEI(predictionList, model)
```

Arguments

predictionList	The results of a predict.model call
model	The surrogate model which was used for the prediction

Value

numeric vector, expected improvement results

Examples

```
spot(,funSphere,c(-2,-3),c(1,2), control =
    list(infillCriterion = infillEI, modelControl = list(target = c("y","s"))))
```

infillExpectedImprovement *infillExpectedImprovement*

Description

Compute the negative logarithm of the Expected Improvement of a set of candidate solutions. Based on mean and standard deviation of a candidate solution, this estimates the expectation of improvement. Improvement considers the amount by which the best known value (best observed value) is exceeded by the candidates. Expected Improvement infill criterion that can be passed to control$modelControl$infillCriterion in order to be used during the optimization in SPOT. Parameters dont have to be specified as this function is ment to be internally by SPOT.

Usage

```
infillExpectedImprovement(predictionList, model)
```

Arguments

predictionList	The results of a predict.model call
model	The surrogate model which was used for the prediction

Value

numeric vector, expected improvement results

Examples

```
spot(,funSphere,c(-2,-3),c(1,2), control =
   list(infillCriterion = infillExpectedImprovement, modelControl = list(target = c("y","s"))))
```

---

init_ring *init_ring*

Description

Initialize ring parameters: generate arrival probabilities for S-Ring. - set beginning states to 0 and initialize random customer states and nElevators - nStates = (number of floors * 2) - 2. For example for 4 floors, its 6 states because the upper and lower state have only one direction and all other have 2 (UP and DOWN)

Usage

```
init_ring(params)
```

Arguments

params	list of
	randomSeed random seed
	nStates number of S-Ring states
	nElevators number of elevators
	probNewCustomer probability pf a customer arrival
	counter Counter: number of waiting customers
	sElevator Vector representing elevators (s)
	sCustomer Vector representing customers (c)
	currentState Current state that is calculated
	nextState Next state that is calculated
	nWeights Number of weights for the perceptron (= 2 * nStates)

Value

list (params) of

`randomSeed` random seed

`nStates` number of S-Ring states

`nElevators` number of elevators

`probNewCustomer` probability pf a customer arrival

`counter` Counter: number of waiting customers

`sElevator` Vector representing elevators (s)

`sCustomer` Vector representing customers (c)

`currentState` Current state that is calculated

`nextState` Next state that is calculated

`nWeights` Number of weights for the perceptron (= 2 * nStates)

Examples

```
params <-list(sElevator=NULL,
  sCustomer=NULL,
  currentState=NULL,
  nextState=NULL,
  counter=NULL,
  nStates=12,
  nElevators=2,
  probNewCustomer=0.1,
  weightsPerceptron=rep(0.1, 24),
  nWeights=NULL,
  nIterations=100,
  randomSeed=1234)

init_ring(params)
```

---

makeMoreFunList *makeMoreFunList*

Description

Generate a list of benchmark functions. Based on the More(1981) paper. Contains the first 13 function from the paper. Function numbers are the same as in the paper.

Usage

```
makeMoreFunList(vector2Matrix = TRUE)
```

Arguments

vector2Matrix	logical. Convert vector input to matrix. Default: TRUE, so it can be used with optim.

Value

list of functions with starting points and optimum points.

References

More, J. J., Garbow, B. S., and Hillstrom, K. E. (1981). Testing unconstrained optimization software. *ACM Transactions on Mathematical Software (TOMS)*, *7*(1), 17-41. doi:10.1145/355934.355936

Examples

```
# Generate function list.
# Here we use the default setting \code{vector2Matrix = TRUE},
# so the function list can be passed to \code{\link[stats]{optim}}.

fl <- makeMoreFunList()
optim(par=c(-1.2,1), fn=fl$funList[[1]])
optim(par=fl$startPointList[[1]], fn=fl$funList[[1]])$value
optim(par=fl$startPointList[[1]], fn=fl$funList[[1]],NULL, method = "CG", hessian = FALSE)$value
optim(fl$startPointList[[1]], fl$funList[[1]],NULL, method = "BFGS", hessian = FALSE)$value
optim(fl$startPointList[[1]], fl$funList[[1]],NULL, method = "L-BFGS-B", hessian = FALSE)$value
```

---

makeSpotFunList *makeSpotFunList*

Description

Generate a list of spot functions

Usage

```
makeSpotFunList(vector2Matrix = TRUE)
```

Arguments

vector2Matrix	logical. Convert vector input to matrix. Default: TRUE, so it can be used with optim.

Value

list of functions

Examples

```
fr <- makeSpotFunList()
optim(c(-1.2,1), fr[[1]])
```

`normalizeMatrix` *Normalize design matrix*

Description

Normalize design by using minimum and maximum of the design values for input space. Each column has entries in the range from `ymin` to `ymax`.

Usage

```
normalizeMatrix(x, ymin, ymax, MARGIN = 2)
```

Arguments

`x`	design matrix in input space
`ymin`	minimum vector of normalized space
`ymax`	maximum vector of normalized space
`MARGIN`	a vector giving the subscripts which the function will be applied over. 1 indicates rows, 2 indicates columns. Default: `2`.

Value

`list` with the following entries:

`y` normalized design matrix in the range [ymin, ymax]

`xmin` min in each column

`xmax` max in each column

See Also

`buildKriging`

Examples

```
set.seed(1)
x <- matrix(c(rep(1,3), rep(2,3),rep(3,3), rep(4,3)),3,4)
## columnwise:
normalizeMatrix(x, ymin=0, ymax=1)
## rowwise
normalizeMatrix(x, ymin=0, ymax=1, MARGIN=1)
# rows with identical values are mapped to the mean:
x <- matrix(rep(0,4),2,2)
normalizeMatrix(x, ymin=0, ymax=1)
```

normalizeMatrix2 *Normalize design 2*

Description

Normalize design with given maximum and minimum in input space. Supportive function for Kriging model, not to be used directly.

Usage

```
normalizeMatrix2(x, ymin, ymax, xmin, xmax)
```

Arguments

x	design matrix in input space (n rows for each point, k columns for each parameter)
ymin	minimum vector of normalized space
ymax	maximum vector of normalized space
xmin	minimum vector of input space
xmax	maximum vector of input space

Value

normalized design matrix

See Also

buildKriging

obj.plgpEI *Wrapper for Expected improvement (Gramacy)*

Description

Wrapper for Expected improvement (Gramacy)

Usage

```
obj.plgpEI(x, fmin, gpi, pred = predGPsep)
```

Arguments

x	matrix of points to calculate EI
fmin	best function value (y) so far
gpi	Gaussian process C-side object
pred	prediction model. Default: predGPsep

Value

negative expected improvement

See Also

plgpEI.

Examples

```
library(laGP)
library(plgp)

ninit <- 12
dim <- 2
X <- designLHD(,rep(0,dim), rep(1,dim), control=list(size=ninit))
y <- funGoldsteinPrice(X)
m <- which.min(y)
ymin <- y[m]
start <- matrix(X[m,], nrow =1)

## Build laGP model
gpi <- newGPsep(X, y, d=0.1, g=1e-8, dK=TRUE)
da <- darg(list(mle=TRUE, max=0.5), designLHD(,rep(0,dim), rep(1,dim), control=list(size=1000)))
mleGPsep(gpi, param="d", tmin=da$min, tmax=da$max, ab=da$ab)
res <- optim(start[1,], obj.plgpEI, method="L-BFGS-B", lower=0, upper=1,
gpi=gpi, pred=predGPsep, fmin=ymin)
xnew <- c(res$par, -res$value)
print(xnew)
deleteGPsep(gpi)
```

---

objectiveFunctionEvaluation

objectiveFunctionEvaluation Objective Function Evaluation

Description

This function handles the evaluation of the objective function in spot. This includes handling of the random number generator stream, variable transformations (transformX) as well as the actual evaluation.

Usage

```
objectiveFunctionEvaluation(x = NULL, xnew, fun, control = list(), ...)
```

Arguments

x	matrix of already known solutions, to determine whether RNG seeds for new solutions need to be incremented.
xnew	matrix of new solutions.
fun	objective function to evaluate the solutions in xnew.
control	control list with the following entries:
	seedFun initial seed to be used for the random number generator seed. Set to NA to avoid using a fixed seed.
	noise: logical parameter specifying whether the target function is noisy.
	verbosity: verbosity. Default: 0.
	transformFun: transformation functions applied to xnew. See transformX
...	parameters passed to fun.

Value

the matrix ynew, which are the observations for fun(xnew)

See Also

spot for more details on the parameters, e.g., fun

transformX

spotControl

Examples

```
## 1) without noise
x <- NULL
xnew <- matrix(1:10, ncol=2)
fun <- funSphere
control <- spotControl(dim(xnew)[2])
control$verbosity <- 0
objectiveFunctionEvaluation(x=x, xnew=xnew, fun=fun, control=control)
##
fun <- funMoo
objectiveFunctionEvaluation(x=x, xnew=xnew, fun=fun, control=control)
## 2) with noise
fun = function(x){funSphere(x) + rnorm(nrow(x))}
control$noise <- TRUE
objectiveFunctionEvaluation(x=x, xnew=xnew, fun=fun, control=control)
## 3) known solutions
x <- matrix(11:20, ncol=2)
xnew <- matrix(1:10, ncol=2)
fun <- funSphere
objectiveFunctionEvaluation(x=x, xnew=xnew, fun=fun, control=control)
## 4) known solutions with noise and repeats
x <- matrix(1:20, ncol=2, byrow=TRUE)
xnew <- matrix(1:10, ncol=2, byrow=TRUE)
```

```
fun = function(x){funSphere(x) + rnorm(nrow(x))}
objectiveFunctionEvaluation(x=x, xnew=xnew, fun=fun, control=control)
## 5) identical solutions with noise and repeats
x <- matrix(1:10, ncol=2, byrow=TRUE)
xnew <- x
fun = function(x){funSphere(x) + rnorm(nrow(x))}
y <- objectiveFunctionEvaluation(x=NULL, xnew=x, fun=fun, control=control)
y1 <- objectiveFunctionEvaluation(x=x, xnew=xnew, fun=fun, control=control)
y2 <- objectiveFunctionEvaluation(x=NULL, xnew=xnew, fun=fun, control=control)
print(cbind(x, y))
print(cbind(xnew, y1))
print(cbind(xnew, y2))
identical(y, y1) # FALSE
identical(y, y2) # TRUE
## 6) known solutions with noise and repeats. function sets seed
x <- matrix(1:20, ncol=2, byrow=TRUE)
xnew <- matrix(1:10, ncol=2, byrow=TRUE)
fun <- function(x,seed){
  set.seed(seed)
  funSphere(x)+rnorm(nrow(x))}
control$seedFun <- 1
y1 <- objectiveFunctionEvaluation(x=x, xnew=xnew, fun=fun, control=control)
y2 <- objectiveFunctionEvaluation(x=x, xnew=xnew, fun=fun, control=control)
identical(y1, y2) # TRUE
control$seedFun <- 2
y3 <- objectiveFunctionEvaluation(x=x, xnew=xnew, fun=fun, control=control)
identical(y1,y3) # FALSE
## 7) spot examples:
res1a <- spot(,function(x,seed){set.seed(seed);funSphere(x)+rnorm(nrow(x))},
c(-2,-3),c(1,2),control=list(funEvals=25,noise=TRUE,seedFun=1))
res1b <- spot(,function(x,seed){set.seed(seed);funSphere(x)+rnorm(nrow(x))},
c(-2,-3),c(1,2),control=list(funEvals=25,noise=TRUE,seedFun=1))
res2 <- spot(,function(x,seed){set.seed(seed);funSphere(x)+rnorm(nrow(x))},
c(-2,-3),c(1,2),control=list(funEvals=25,noise=TRUE,seedFun=2))
sprintf("Should be equal: %f = %f. Should be different:  %f", res1a$ybest,
res1b$ybest, res2$ybest)
```

---

ocbaRanking *ocbaRanking*

Description

Return the ocba ranking (xbest, ybest) for noisy optimization

Usage

```
ocbaRanking(x, y, fun, control, ...)
```

Arguments

x	matrix of x values
y	matrix of y values, one dimensional!
fun	objective function
control	control list, see spotControl
...	additional arguments to fun

Details

Based on repeatsOCBA

Value

(x,y) matrix of sorted (by y) values. In case of noise are these values aggregated (y-mean) values.

---

optimDE *Minimization by Differential Evolution*

Description

For minimization, this function uses the "DEoptim" method from the codeDEoptim package. It is basically a wrapper, to enable DEoptim for usage in SPOT.

Usage

```
optimDE(x = NULL, fun, lower, upper, control = list(), ...)
```

Arguments

x	optional start point
fun	objective function, which receives a matrix x and returns observations y
lower	boundary of the search space
upper	boundary of the search space
control	list of control parameters
	funEvals Budget, number of function evaluations allowed. Default is 200.
	populationSize Population size or number of particles in the population. Default is 10*dimension.
...	passed to fun

Value

list, with elements

x archive of the best member at each iteration

y archive of the best value of fn at each iteration

xbest best solution

ybest best observation

count number of evaluations of fun

Examples

```
res <- optimDE(,lower = c(-10,-20),upper=c(20,8),fun = funSphere)
res$ybest
optimDE(x = matrix(rep(1,6), 3, 2),lower = c(-10,-20),upper=c(20,8),fun = funSphere,
   control = list(funEvals=100, populationSize=20))
#Compare to DEoptim:
require(DEoptim)
set.seed(1234)
DEoptim(function(x){funRosen(matrix(x,1))}, lower=c(-10,-10), upper=c(10,10),
  DEoptim.control(strategy = 2,bs = FALSE, N = 20, itermax = 28, CR = 0.7, F = 1.2,
  trace = FALSE, p = 0.2, c = 0, reltol = sqrt(.Machine$double.eps), steptol = 200 ))
set.seed(1234)
optimDE(, fun=funRosen, lower=c(-10,-10), upper= c(10,10),
   control = list( populationSize = 20, funEvals = 580, F = 1.2, CR = 0.7))
```

---

optimES *Evolution Strategy*

Description

This is an implementation of an Evolution Strategy.

Usage

```
optimES(x = NULL, fun, lower, upper, control = list(), ...)
```

Arguments

x	optional start point, not used
fun	objective function, which receives a matrix x and returns observations y
lower	is a vector that defines the lower boundary of search space (this also defines the dimensionality of the problem)
upper	is a vector that defines the upper boundary of search space (same length as lower)
control	list of control parameters. The control list can contain the following settings:
	funEvals number of function evaluations, stopping criterion, default is 500

mue number of parents, default is `10`

nu selection pressure. That means, number of offspring (lambda) is mue multiplied with nu. Default is `10`

mutation string of mutation type, default is `1`

sigmaInit initial sigma value (step size), default is `1.0`

nSigma number of different sigmas, default is `1`

tau0 number, default is `0.0`. tau0 is the general multiplier.

tau number, learning parameter for self adaption, i.e. the local multiplier for step sizes (for each dimension).default is `1.0`

rho number of parents involved in the procreation of an offspring (mixing number), default is `"bi"`

sel number of selected individuals, default is `1`

stratReco Recombination operator for strategy variables. `1`: none. `2`: dominant/discrete (default). `3`: intermediate. `4`: variation of intermediate recombination.

objReco Recombination operator for object variables. `1`: none. `2`: dominant/discrete (default). `3`: intermediate. `4`: variation of intermediate recombination.

maxGen number of generations, stopping criterion, default is `Inf`

seed number, random seed, default is `1`

noise number, value of noise added to fitness values, default is `0.0`

verbosity defines output verbosity of the ES, default is `0`

plotResult boolean, specifies if results are plotted, default is `FALSE`

logPlotResult boolean, defines if plot results should be logarithmic, default is `FALSE`

sigmaRestart number, value of sigma on restart, default is `0.1`

preScanMult initial population size is multiplied by this number for a pre-scan, default is `1`

globalOpt termination criterion on reaching a desired optimum value, default is `rep(0,dimension)`

`...` additional parameters to be passed on to `fun`

Value

list, with elements

`x` NULL, currently not used

`y` NULL, currently not used

`xbest` best solution

`ybest` best observation

`count` number of evaluations of `fun`

Examples

```
cont <- list(funEvals=100)
optimES(fun=funSphere,lower=rep(0,2), upper=rep(1,2), control= cont)
```

optimGenoud *Minimization by GENetic Optimization Using Derivatives*

Description

For minimization, this function uses the "genoud" method from the codergenoud package. It is basically a wrapper, to enable genoud for usage in SPOT.

Usage

```
optimGenoud(x = NULL, fun, lower, upper, control = list(), ...)
```

Arguments

x	optional start point, not used
fun	objective function, which receives a matrix x and returns observations y
lower	boundary of the search space
upper	boundary of the search space
control	list of control parameters
	funEvals Budget, number of function evaluations allowed. Default is 100.
	populationSize Population size, number of individuals in the population. Default is 10*dimension.
...	passed to fun

Value

list, with elements

x NULL, currently not used

y NULL, currently not used

xbest best solution

ybest best observation

count number of evaluations of fun

Examples

```
res <- optimGenoud(,fun = funSphere,lower = c(-10,-20),upper=c(20,8))
res$ybest
```

optimLagp *Interface to minimization based on Gramacy's lagp package*

Description

Implements Gramacy's plgp package based optimization using expected improvement. Example from chapter 7 in the surrogate book.

Usage

```
optimLagp(x = NULL, fun, lower, upper, control = list(), ...)
```

Arguments

x	optional matrix of points to be included in the evaluation
fun	objective function, which receives a matrix x and returns observations y
lower	boundary of the search space
upper	boundary of the search space
control	list of control parameters
	funEvals Budget, number of function evaluations allowed. Default: 100.
	retries Number of retries for design generation, used by designLHD. Default: 100.
...	passed to fun

Value

list, with elements

x archive of evaluated solutions

y archive of observations

xbest best solution

ybest best observation

count number of evaluations of fun

message success message

Examples

```
res <- optimLHD(,fun = funSphere,lower = c(-10,-20),upper=c(20,8))
res$ybest
```

optimLBFGSB *Minimization by L-BFGS-B*

Description

For minimization, this function uses the "L-BFGS-B" method from the optim function, which is part of the codestats package. It is basically a wrapper, to enable L-BFGS-B for usage in SPOT.

Usage

```
optimLBFGSB(x = NULL, fun, lower, upper, control = list(), ...)
```

Arguments

x	optional matrix of points. Only first point (row) is used as startpoint.
fun	objective function, which receives a matrix x and returns observations y
lower	boundary of the search space
upper	boundary of the search space
control	list of control parameters
	funEvals Budget, number of function evaluations allowed. Default is 100.
	All other control parameters accepted by the optim function can be used, too, and are passed to optim.
...	passed to fun

Value

list, with elements

x NA, not used

y NA, not used

xbest best solution

ybest best observation

count number of evaluations of fun (estimated from the more complicated "counts" variable returned by optim)

message termination message returned by optim

Examples

```
res <- optimLBFGSB(,fun = funSphere,lower = c(-10,-20),upper=c(20,8))
res$ybest
```

optimLHD *Minimization by Latin Hypercube Sampling*

Description

This uses Latin Hypercube Sampling (LHS) to optimize a specified target function. A Latin Hypercube Design (LHD) is created with designLHD, then evaluated by the objective function. All results are reported, including the best (minimal) objective value, and corresponding design point.

Usage

```
optimLHD(x = NULL, fun, lower, upper, control = list(), ...)
```

Arguments

x	optional matrix of points to be included in the evaluation
fun	objective function, which receives a matrix x and returns observations y
lower	boundary of the search space
upper	boundary of the search space
control	list of control parameters
	funEvals Budget, number of function evaluations allowed. Default: 100.
	retries Number of retries for design generation, used by designLHD. Default: 100.
...	passed to fun

Value

list, with elements

x archive of evaluated solutions

y archive of observations

xbest best solution

ybest best observation

count number of evaluations of fun

message success message

Examples

```
res <- optimLHD(,fun = funSphere,lower = c(-10,-20),upper=c(20,8))
res$ybest
```

optimNLOPTR *optimNLOPTR. Minimization by NLOPT*

Description

#' This is a wrapper that employs the nloptr function from the package of the same name. The nloptr function itself is an interface to the nlopt library, which contains a wide selection of different optimization algorithms.

Usage

```
optimNLOPTR(x = NULL, fun, lower, upper, control = list(), ...)
```

Arguments

x	optional matrix of points to be included in the evaluation (only first row will be used)
fun	objective function, which receives a matrix x and returns observations y
lower	boundary of the search space
upper	boundary of the search space
control	named list, with the options for nloptr. These will be passed to nloptr as arguments. In addition, the following parameter can be used to set the function evaluation budget:
	funEvals Budget, number of function evaluations allowed. Default: 100.
...	passed to fun
	Note that the arguments x, fun, lower and upper will be mapped to the corresponding arguments of nloptr: x0, eval_f, lb and ub.

Value

list, with elements

x archive of evaluated solutions

y archive of observations

xbest best solution

ybest best observation

count number of evaluations of fun

message success message

Examples

```
##simple example:
res <- optimNLOPTR(,fun = funSphere,lower = c(-10,-20),upper=c(20,8))
res
##with an inequality constraint:
contr <- list()  #control list
##specify constraint
contr$eval_g_ineq <- function(x) 1+x[1]-x[2]
res <- optimNLOPTR(,fun=funSphere,lower=c(-10,-20),upper=c(20,8),control=contr)
res
```

---

optimRSfun *Random search surrogate-optimizer*

Description

This function is used to emulate uniform random search with SPOT. It is used as the optimizer that searches for new candidates. It returns a single uniform random sample within the given lower and upper bounds of the search space.

Usage

```
optimRSfun(x, fun, lower, upper, control, ...)
```

Arguments

x	start guess, not used.
fun	objective function to be evaluated via random search.
lower	bound on the independent variables (search space).
upper	bound on the independent variables (search space).
control	not used.
...	additional arguments, not used.

Value

list

perceptron *perceptron*

Description

Perceptron to calculate decisions

Usage

```
perceptron(currentState, nStates, sElevator, sCustomer, weightsPerceptron)
```

Arguments

currentState	current state for decision (num)
nStates	numer of states (int)
sElevator	elevators vector (logical)
sCustomer	customer vector (logical)
weightsPerceptron	Weight vector (num)

Details

Number of weights in NN controller is 2xnStates, for each state (sElevator/sCustomer) there is one input

Value

logical pass or take decision

plgpEI *Expected improvement (Gramacy)*

Description

Expected improvement (Gramacy)

Usage

```
plgpEI(gpi, x, fmin, pred = predGPsep)
```

Arguments

gpi	Gaussian process C-side object
x	matrix of points to calculate EI
fmin	best function value (y) so far
pred	prediction model. Default: predGPsep

Value

ei expected improvement

Examples

```
library(laGP)
library(plgp)

ninit <- 12
dim <- 2
X <- designLHD(,rep(0,dim), rep(1,dim), control=list(size=ninit))
y <- funGoldsteinPrice(X)
m <- which.min(y)
ymin <- y[m]
start <- matrix(X[m,], nrow =1)

## 1. Build SPOT BO Model
m1 <- buildBO(x = X, y = y, control = list(target="ei"))
yy <- predict(object = m1, newdata = start)
ei1 <- matrix(yy$ei, ncol = 1)
## Show mue and s
mue <- matrix(yy$y, ncol = 1)
s2 <- matrix(yy$s, ncol = 1)

## 2. Build laGP model
gpi <- newGPsep(X, y, d=0.1, g=1e-8, dK=TRUE)
da <- darg(list(mle=TRUE, max=0.5), designLHD(,rep(0,dim), rep(1,dim), control=list(size=1000)))
mleGPsep(gpi, param="d", tmin=da$min, tmax=da$max, ab=da$ab)
ei2 <- plgpEI(gpi=gpi, x=start, fmin=ymin)
deleteGPsep(gpi)
```

---

plot.spotSeverity *Plot method for spotSeverity*

Description

Plot method for spotSeverity

Usage

```
## S3 method for class 'spotSeverity'
plot(
  x,
  add = FALSE,
  rangeLeft = -1,
  rangeRight = 1,
  plotSev = TRUE,
```

```
  plotPow = FALSE,
  cl = "black",
  xlab = "x",
  ylab = "y",
  ...
)
```

Arguments

x	severity object
add	default value is FALSE
rangeLeft	range default:-1
rangeRight	range default:1
plotSev	logical. plot severity. Default: TRUE
plotPow	logical. plot power. Default: FALSE
cl	color, e.g., c("black", "red", "green", " blue" , "brown","cyan", "darkred", "gray", "green", "magenta", "orange")
xlab	x axis label
ylab	y axis label
...	additional parameters

Value

description of return value

Examples

```
### Example from D G Mayo and A Spanos.
### Severe Testing as a Basic Concept in a NeymanPearson Philosophy of Induction.
### British Journal for the Philosophy of Science, 57:323357, 2006. (fig 2):
x0 <- 12.1
mu1 <- seq(11.9,13,0.01)
n <- 100
sigma <- 2
alpha <- 0.025
tdist <- FALSE
plot(mu1, spotSeverity(xbar=x0, mu0=0, mu1=mu1, n=n, sigma=sigma, alpha=alpha,
tdist=tdist)$severity, type = "l", ylim=c(0,1), col="blue")
abline(h=0)
abline(h=1)
 abline(h=0.95)
abline(v=12.43)
### plot power:
mu0 <- 12
points(mu1, spotPower(alpha, mu0, mu1, n, sigma), type = "l", ylim=c(0,1),
col="green")
abline(v=12.72)
```

```
## Fig 13.11 in Span19a
p <- spotSeverity(xbar=10, mu0=10, mu1= 10.2, n=100, sigma = 1, alpha = 0.05, tdist = FALSE)
plot(p, rangeLeft = 10, rangeRight = 10.5, plotPow = TRUE)
```

---

plotBestObj *Plot Best Objective Value*

Description

Plot Best Objective Value

Usage

```
plotBestObj(y, end = length(y))
```

Arguments

y	result vector
end	length. Default: `length(y)`

Value

plot

---

plotData *Interpolated plot*

Description

A (filled) contour or perspective plot of a data set with two independent and one dependent variable. The plot is generated by some interpolation or regression model. By default, the `loess` function is used.

Usage

```
plotData(
  x,
  y,
  which = 1:2,
  constant = x[which.min(y), ],
  model = buildLOESS,
  modelControl = list(),
  xlab = c("x1", "x2"),
  ylab = "y",
  type = "filled.contour",
  ...
)
```

Arguments

x	independent variables, or input variables. this should be a matrix of at least two columns and several rows. If more than two columns are present, all will be used for fitting the model. The parameter which will determine which of these will be plotted, and the parameter constant will determine the values of all parameters that are not varied.
y	dependent, or observed output variable to be interpolated/regressed and plotted.
which	a vector with two elements, each an integer giving the two independent variables of the plot (the integers are indices of the respective data set, i.e., columns of x). All other parameters will be fixed to the best known solution, i.e., the one with minimal y-value.
constant	a numeric vector that states for each variable a constant value that it will take on if it is not varied in the plot. This affects the parameters not selected by the which parameter. By default, this will be fixed to the best known solution, i.e., the one with minimal y-value, according to which.min(object$y). The length of this numeric vector should be the same as the number of columns in object$x
model	the model building function to be used, by default buildLOESS.
modelControl	control list of the chosen model building function.
xlab	a vector of characters, giving the labels for each of the two independent variables
ylab	character, the value of the dependent variable predicted by the corresponding model
type	string describing the type of the plot: "filled.contour" (default), "contour", "persp" (perspective), or "persp3d" plot. Note that "persp3d" is based on the plotly package and will work in RStudio, but not in the standard RGui.
...	additional parameters passed to the contour or filled.contour function

See Also

plotFunction, plotModel

Examples

```
## generate random test data
testfun <- function (x) sum(x^2)
set.seed(1)
k <- 30
x <- cbind(runif(k)*15-5,runif(k)*15)
y <- as.matrix(apply(x,1,testfun))
plotData(x,y)
plotData(x,y,type="contour")
plotData(x,y,type="persp")
```

plotFunction *Surface plot of a function*

Description

A (filled) contour plot or perspective / surface plot of a function.

Usage

```
plotFunction(
  f = function(x) {
     rowSums(x^2)
 },
  lower = c(0, 0),
  upper = c(1, 1),
  type = "filled.contour",
  s = 100,
  xlab = "x1",
  ylab = "x2",
  zlab = "y",
  color.palette = terrain.colors,
  title = " ",
  levels = NULL,
  points1,
  points2,
  pch1 = 20,
  pch2 = 8,
  lwd1 = 1,
  lwd2 = 1,
  cex1 = 1,
  cex2 = 1,
  col1 = "red",
  col2 = "black",
  theta = -40,
  phi = 40,
  ...
)
```

Arguments

f	function to be plotted. The function should either be able to take two vectors or one matrix specifying sample locations. i.e. `z=f(X)` or `z=f(x2,x1)` where Z is a two column matrix containing the sample locations `x1` and `x2`.
lower	boundary for x1 and x2 (defaults to `c(0,0)`).
upper	boundary (defaults to `c(1,1)`).

type	string describing the type of the plot: "filled.contour" (default), "contour", "persp" (perspective), or "persp3d" plot. Note that "persp3d" is based on the plotly package and will work in RStudio, but not in the standard RGui.
s	number of samples along each dimension. e.g. f will be evaluated s^2 times.
xlab	lable of first axis
ylab	lable of second axis
zlab	lable of third axis
color.palette	colors used, default is terrain.color
title	of the plot
levels	number of levels for the plotted function value. Will be set automatically with default NULL.. (contour plots only)
points1	can be omitted, but if given the points in this matrix are added to the plot in form of dots. Contour plots and persp3d only. Contour plots expect matrix with two columns for coordinates. 3Dperspective expects matrix with three columns, third column giving the corresponding observed value of the plotted function.
points2	can be omitted, but if given the points in this matrix are added to the plot in form of crosses. Contour plots and persp3d only. Contour plots expect matrix with two columns for coordinates. 3Dperspective expects matrix with three columns, third column giving the corresponding observed value of the plotted function.
pch1	pch (symbol) setting for points1 (default: 20). (contour plots only)
pch2	pch (symbol) setting for points2 (default: 8). (contour plots only)
lwd1	line width for points1 (default: 1). (contour plots only)
lwd2	line width for points2 (default: 1). (contour plots only)
cex1	cex for points1 (default: 1). (contour plots only)
cex2	cex for points2 (default: 1). (contour plots only)
col1	color for points1 (default: "black"). (contour plots only)
col2	color for points2 (default: "black"). (contour plots only)
theta	angle defining the viewing direction. theta gives the azimuthal direction and phi the colatitude. (persp plot only)
phi	angle defining the viewing direction. theta gives the colatitude. (persp plot only)
...	additional parameters passed to contour or filled.contour

See Also

plotData, plotModel

Examples

```
plotFunction(function(x){rowSums(x^2)},c(-5,0),c(10,15))
plotFunction(function(x){rowSums(x^2)},c(-5,0),c(10,15),type="contour")
plotFunction(function(x){rowSums(x^2)},c(-5,0),c(10,15),type="persp")
```

plotModel *Surface plot of a model*

Description

A (filled) contour or perspective plot of a fitted model.

Usage

```
plotModel(
  object,
  which = if (ncol(object$x) > 1 & tolower(type) != "singledim") {
     1:2
 } else {

       1
 },
  constant = object$x[which.min(object$y), ],
  xlab = paste("x", which, sep = ""),
  ylab = "y",
  type = "filled.contour",
  ...
)
```

Arguments

object	fit created by a modeling function, e.g., buildRandomForest.
which	a vector with two elements, each an integer giving the two independent variables of the plot (the integers are indices of the respective data set).
constant	a numeric vector that states for each variable a constant value that it will take on if it is not varied in the plot. This affects the parameters not selected by the which parameter. By default, this will be fixed to the best known solution, i.e., the one with minimal y-value, according to which.min(object$y). The length of this numeric vector should be the same as the number of columns in object$x
xlab	a vector of characters, giving the labels for each of the two independent variables.
ylab	character, the value of the dependent variable predicted by the corresponding model.
type	string describing the type of the plot: "filled.contour" (default), "contour", "persp" (perspective), or "persp3d" plot. Note that "persp3d" is based on the plotly package and will work in RStudio, but not in the standard RGui.
...	additional parameters passed to the contour or filled.contour function.

See Also

plotFunction, plotData

Examples

```
## generate random test data
testfun <- function (x) sum(x^2)
set.seed(1)
k <- 30
x <- cbind(runif(k)*15-5,runif(k)*15,runif(k)*2-7,runif(k)*5+22)
y <- as.matrix(apply(x,1,testfun))
fit <- buildLM(x,y)
plotModel(fit)
plotModel(fit,type="contour")
plotModel(fit,type="persp")
plotModel(fit,which=c(1,4))
plotModel(fit,which=2:3)
```

---

plotPCA *plotPCA*

Description

plotPCA returns a 2D plot of optimization data in it's own space using buildPCA. It plots first two PCAs by default.

Usage

```
plotPCA(x, control = list())
```

Arguments

x	dataset of parameters to be transformed & plotted
control	control list

Value

It returns a plot image.

Author(s)

Alpar Gür <alpar.guer@smail.th-koeln.de>

See Also

buildPCA, biplot

Examples

```
# define objective function
funGauss <- function (x) {
  gauss <- function(par) {
    y <- c(0.0009, 0.0044, 0.0175, 0.0540, 0.1295, 0.2420, 0.3521, 0.3989,
           0.3521, 0.2420, 0.1295, 0.0540, 0.0175, 0.0044, 0.0009)
    m <- 15
    x1 <- par[1]
    x2 <- par[2]
    x3 <- par[3]

    fsum <- 0
    for (i in 1:m) {
      ti <- (8 - i) * 0.5
      f <- x1 * exp(-0.5 * x2 * (ti - x3) ^ 2) - y[i]
      fsum <- fsum + f * f
    }
    return(fsum)
  }
  matrix(apply(x, # matrix
               1, # margin (apply over rows)
               gauss),
         , 1) # number of columns
}

# define starting point
x1 <- matrix(c(1,1,1),1,)
funGauss(x1)

# define boundaries
lower = c(-0.001,-0.007,-0.003)
upper = c(0.5,1.0,1.1)

res <- spot(,funGauss, lower=lower, upper=upper, control=list(funEvals=15))

control = list(scale=TRUE) #pca control list, # scale the variables

plotPCA(res$x, control=control) # plot first two PCAs
```

---

plotPCAvariance *plotPCAvariance*

Description

plotPCAvariance illustrates the total variance within the dataset. It plots the effectiveness of each principal component and can be used to decide how many and which prinicpal components to plot. In order to create this plot, users don't need to build PCA beforehand since it handles this process automatically.

Usage

```
plotPCAvariance(x)
```

Arguments

x	dataset of parameters to be transformed & plotted

Value

It returns a plot image.

Author(s)

Alpar Gür <alpar.guer@smail.th-koeln.de>

See Also

buildPCA

Examples

```
# objective function
funBard <- function (x) {
  bard <- function(par) {
    y <- c(0.14, 0.18, 0.22, 0.25, 0.29, 0.32, 0.35, 0.39, 0.37, 0.58,
           0.73, 0.96, 1.34, 2.10, 4.39)
    m <- 15
    x1 <- par[1]
    x2 <- par[2]
    x3 <- par[3]

    fsum <- 0
    for (u in 1:m) {
      v <- 16 - u
      w <- min(u, v)
      f <- y[u] - (x1 + u / (v * x2 + w * x3))
      fsum <- fsum + f * f
    }
    return(fsum)
  }
  matrix(apply(x, # matrix
               1, # margin (apply over rows)
               bard),
         , 1) # number of columns
}

# starting point
x1 <- matrix(c(1,1),1,)
funBard(x1)

#boundaries
lower = c(-0.001,-0.007,-0.003)
```

```
upper = c(0.5,1.0,1.1)

res <- spot(,funBard, lower=lower, upper=upper, control=list(funEvals=15))

plotPCAvariance(res$x) # plot variance within the dataset
```

`predict.cvModel` *predict.cvModel*

Description

Predict with the cross validated model produced by `buildCVModel`.

Usage

```
## S3 method for class 'cvModel'
predict(object, newdata, ...)
```

Arguments

`object`	CV model (settings and parameters) of class `cvModel`.
`newdata`	design matrix to be predicted
`...`	Additional parameters passed to the model

Value

prediction results: list with predicted mean ('y'), estimated uncertainty ('y'), linearly adapted uncertainty ('sLinear')

`predict.spotBOModel` *Prediction method for bayesian optimization model*

Description

Wrapper for `predict.spotBOModel`.

Usage

```
## S3 method for class 'spotBOModel'
predict(object, newdata, ...)
```

Arguments

`object`	fit of the model, an object of class `"spotBOModel"`, produced by `buildBO`.
`newdata`	matrix of new data.
`...`	not used

Value

list with predicted mean `y`, uncertainty / standard deviation `s` (optional) and expected improvement `ei` (optional). Whether `s` and `ei` are returned is specified by the vector of strings `object$target`, which then contains `"s"` and `"ei"`.

---

prepareBestObjectiveVal *Preprocess y Values to Plot Best Objective Value*

Description

Preprocess y Values to Plot Best Objective Value

Usage

```
prepareBestObjectiveVal(y, end = length(y))
```

Arguments

`y`	result vector
`end`	length. Default: `length(y)`

Value

prog

---

repeatsOCBA *Optimal Computing Budget Allocation*

Description

Simple interface to the Optimal Computing Budget Allocation algorithm.

Usage

```
repeatsOCBA(x, y, budget, verbosity = 0)
```

Arguments

`x`	matrix of samples. Identical rows indicate repeated evaluations. Any sample should be evaluated at least twice, to get an estimate of the variance.
`y`	observations of the respective samples. For repeated evaluations, y should differ (variance not zero).
`budget`	of additional evaluations to be allocated to the samples.
`verbosity`	verbosity

Value

A vector that specifies how often each solution should be evaluated.

References

Chun-hung Chen and Loo Hay Lee. 2010. Stochastic Simulation Optimization: An Optimal Computing Budget Allocation (1st ed.). World Scientific Publishing Co., Inc., River Edge, NJ, USA.

See Also

repeatsOCBA calls OCBA, which also provides some additional details.

Examples

```
x <- matrix(c(1:3,1:3),9,2)
y <- runif(9)
repeatsOCBA(x,y,10)
```

---

resBench01 *result from the vignette benchmark*

Description

A data set The corresponding code can be found in the vignette SPOTVignetteNutshell.

Usage

```
resBench01
```

Format

A list of

xbest num [1, 1:100] 188 45

resSpot — *S-Ring Simulation Data Obtained With SPOT*

Description

A data set based on evaluations of the `funCosts` function. Second experiment (extension of the first design) The corresponding code can be found in the vignette SPOTVignetteElevator.

Usage

```
resSpot
```

Format

A list of 7:

xbest num [1, 1:2] 188 45

ybest num [1, 1] 1e+07

x num [1:87, 1:2] 17.4 143.6 89.9 28.7 51.4 ...

y num [1:87, 1] 1e+07 1e+07 1e+07 1e+07 1e+07 ...

count num 0.1 0.1 0.1 0.1 0.1 1 1 1 1 1 ...

msg chr "budget exhausted"

modelFit List of 32

resSpot2 — *S-Ring Simulation Data Obtained With SPOT*

Description

A data set based on evaluations of the `funCosts` function. Second experiment (extension of the second design) The corresponding code can be found in the vignette SPOTVignetteElevator.

Usage

```
resSpot2
```

Format

A list of 7:

xbest num [1, 1:2] 188 45

ybest num [1, 1] 1e+07

x num [1:87, 1:2] 17.4 143.6 89.9 28.7 51.4 ...

y num [1:87, 1] 1e+07 1e+07 1e+07 1e+07 1e+07 ...

count num 0.1 0.1 0.1 0.1 0.1 1 1 1 1 1 ...

msg chr "budget exhausted"

modelFit List of 32

`ring` *ring*

Description

main function which iterates the ring

Usage

```
ring(params)
```

Arguments

`params`	list of
	`randomSeed` random seed
	`nStates` number of S-Ring states
	`nElevators` number of elevators
	`probNewCustomer` probability pf a customer arrival
	`counter` Counter: number of waiting customers
	`sElevator` Vector representing elevators (s)
	`sCustomer` Vector representing customers (c)
	`currentState` Current state that is calculated
	`nextState` Next state that is calculated
	`nWeights` Number of weights for the perceptron (= 2 * nStates)

Value

number of waiting customers (estimation)

runOptim *runOptim*

Description

Run optim on a list of spot benchmark functions

Usage

```
runOptim(
  fl = makeMoreFunList(),
  method = "Nelder-Mead",
  n = 2,
  k = 1:length(makeMoreFunList()$funList),
  verbosity = 0
)
```

Arguments

fl	function list. Generated with one of the function list generators in spot, e.g., makeSpotFunList or makeMoreFunList. Default: makeMoreFunList.
method	The method used by optim: "Nelder-Mead", "BFGS", "CG", "L-BFGS-B", "SANN", or "Brent". Default: "Nelder-Mead".
n	repeats. If n >1 , different start points (randomized) will be used. Default: n=2.
k	subset of benchmark functions. Default: 1:length(makeMoreFunList()$funList), i.e., all implemented functions.
verbosity	Level 0 shows no output (default).

Value

res. data.frame with results: c("f", "r", "y")

Examples

```
summary(runOptim(k=1)$y)
summary(runOptim(k=1, method="CG")$y)
```

runSpotBench *runSpotBench*

Description

Run spot on a list of spot benchmark functions

Usage

```
runSpotBench(
  fl = makeMoreFunList(),
  control = list(),
  n = 2,
  k = 1:length(makeMoreFunList()$funList),
  verbosity = 0
)
```

Arguments

fl	function list. Generated with one of the function list generators in spot, e.g., makeSpotFunList or makeMoreFunList. Default: makeMoreFunList.
control	The control list used by spot.
n	repeats. If n >1 , different start points (randomized) will be used. Default: n=2.
k	subset of benchmark functions. Default: 1:length(makeMoreFunList()$funList), i.e., all implemented functions.
verbosity	Level 0 shows no output (default).

Value

res. data.frame with results: c("f", "r", "y")

Examples

```
summary(runSpotBench(k=1)$y)
```

sann2spot *Interface SANN to SPOT*

Description

Provide an interface for tuning SANN. The interface function receives a `matrix` where each row is proposed parameter setting (‘temp‘, ‘tmax‘), and each column specifies the parameters. It generates a $(n,1)$-matrix as output, where n is the number of (‘temp‘, ‘tmax‘) parameter settings.

Usage

```
sann2spot(algpar, par = c(10, 10), fn, maxit = 100, ...)
```

Arguments

`algpar`	`matrix` algorithm parameters.
`par`	Initial values for the parameters to be optimized over.
`fn`	A function to be minimized (or maximized), with first argument the vector of parameters over which minimization is to take place. It should return a scalar result.
`maxit`	Total number of function evaluations: there is no other stopping criterion. Defaults to 10000.
`...`	further arguments for `optim`

Value

`matrix` of results (performance values)

Examples

```
sphere <- function(x){sum(x^2)}
algpar <- matrix(c(1:10, 1:10), 10,2)
sann2spot(algpar, fn = sphere)
```

satter *Satterthwaite Function*

Description

The Satterthwaite function can be used to estimate the magnitude of the variance component (sigma_beta)^2, when the random factor has significant main effects.

Usage

```
satter(MScoeff, MSi, dfi, alpha = 0.05)
```

Arguments

MScoeff	coefficients c_1, c_2
MSi	mean squared values
dfi	degrees of freedom
alpha	error probability

Details

Note, the output from the satter() procedure is sigma_beta.

Value

vector with 1. estimate of variance 2. degrees of freedom, 3. lower value of 1-alpha confint 4. upper value of 1-alpha confint

Examples

```
res <- satter(MScoeff= c(1/4, -1/4)
              , MSi = c(394.9, 73.3)
              , dfi = c(4,3)
              , alpha = 0.1)
```

---

simulate.kriging *Kriging Simulation*

Description

(Conditional) Simulation at given locations, with a model fit resulting from buildKriging. In contrast to prediction or estimation, the goal is to reproduce the covariance structure, rather than the data itself. Note, that the conditional simulation also reproduces the training data, but has a two times larger error than the Kriging predictor.

Usage

```
## S3 method for class 'kriging'
simulate(
  object,
  nsim = 1,
  seed = NA,
  xsim,
  method = "decompose",
  conditionalSimulation = TRUE,
  Ncos = 10,
  returnAll = FALSE,
  ...
)
```

Arguments

object	fit of the Kriging model (settings and parameters), of class kriging.
nsim	number of simulations
seed	random number generator seed. Defaults to NA, in which case no seed is set
xsim	list of samples in input space, to be simulated at
method	"decompose" (default) or "spectral", specifying the method used for simulation. Note that "decompose" is can be preferable, since it is exact but may be computationally infeasible for high-dimensional xsim. On the other hand, "spectral" yields a function that can be evaluated at arbitrary sample locations.
conditionalSimulation	logical, if set to TRUE (default), the simulation is conditioned with the training data of the Kriging model. Else, the simulation is non-conditional.
Ncos	number of cosine functions (used with method="spectral" only)
returnAll	if set to TRUE, a list with the simulated values (y) and the corresponding covariance matrix (covar) of the simulated samples is returned.
...	further arguments, not used

Value

Returned value depends on the setting of object$simulationReturnAll

References

N. A. Cressie. Statistics for Spatial Data. JOHN WILEY & SONS INC, 1993.

C. Lantuejoul. Geostatistical Simulation - Models and Algorithms. Springer-Verlag Berlin Heidelberg, 2002.

See Also

buildKriging, predict.kriging

---

simulateFunction *simulateFunction*

Description

Simulation-based Function Generator. Generate functions via simulation of Kriging models, e.g., for assessment of optimization algorithms with non-conditional or conditional simulation, based on real-world data.

Usage

```
simulateFunction(
  object,
  nsim = 1,
  seed = NA,
  method = "spectral",
  xsim = NA,
  Ncos = 10,
  conditionalSimulation = TRUE
)
```

Arguments

object	an object generated by buildKriging
nsim	the number of simulations, or test functions, to be created
seed	a random number generator seed. Defaults to NA; which means no seed is set. For sake of reproducibility, set this to some integer value.
method	"decompose" (default) or "spectral", specifying the method used for simulation. Note that "decompose" is can be preferable, since it is exact but may be computationally infeasible for high-dimensional xsim. On the other hand, "spectral" yields a function that can be evaluated at arbitrary sample locations.
xsim	list of samples in input space, for simulation (only used for decomposition-based simulation, not for spectral method)
Ncos	number of cosine functions (used with method="spectral" only)
conditionalSimulation	whether (TRUE) or not (FALSE) to use conditional simulation

Value

a list of functions, where each function is the interpolation of one simulation realization. The length of the list depends on the nsim parameter.

References

N. A. Cressie. Statistics for Spatial Data. JOHN WILEY & SONS INC, 1993.

C. Lantuejoul. Geostatistical Simulation - Models and Algorithms. Springer-Verlag Berlin Heidelberg, 2002.

See Also

buildKriging, simulate.kriging

spot *spot*

Description

Sequential Parameter Optimization. This is one of the main interfaces for using the SPOT package. Based on a user-given objective function and configuration, `spot` finds the parameter setting that yields the lowest objective value (minimization). To that end, it uses methods from the fields of design of experiment, statistical modeling / machine learning and optimization.

Usage

```
spot(x = NULL, fun, lower, upper, control = list(), ...)
```

Arguments

`x`	is an optional start point (or set of start points), specified as a matrix. One row for each point, and one column for each optimized parameter.
`fun`	is the objective function. It should receive a matrix x and return a matrix y. In case the function uses external code and is noisy, an additional seed parameter may be used, see the `control$seedFun` argument below for details. Mostly, fun must have format y = f(x, ...). If a noisy function requires some specific seed handling, e.g., in some other non-R code, a seed can be passed to fun. For that purpose, the user must specify `control$noise = TRUE` and fun should be `fun(x, seed, ...)`
`lower`	is a vector that defines the lower boundary of search space. This determines also the dimensionality of the problem.
`upper`	is a vector that defines the upper boundary of search space.
`control`	is a list with control settings for spot. See `spotControl`.
`...`	additional parameters passed to `fun`.

Value

This function returns a list with:

`xbest` Parameters of the best found solution (matrix).

`ybest` Objective function value of the best found solution (matrix).

`x` Archive of all evaluation parameters (matrix).

`y` Archive of the respective objective function values (matrix).

`count` Number of performed objective function evaluations.

`msg` Message specifying the reason of termination.

`modelFit` The fit of the last build model, i.e., an object returned by the last call to the function specified by `control$model`.

Examples

```
## Only a few examples. More examples can be found in the vignette and in
## the paper "In a Nutshell -- The Sequential Parameter Optimization Toolbox",
## see https://arxiv.org/abs/1712.04076

## 1. Most simple example: Kriging + LHS search + predicted mean optimization
## (not expected improvement)
set.seed(1)
res <- spot(x=NULL,funSphere,c(-2,-3),c(1,2),
             control=list(funEvals=15))
res$xbest
res$ybest

## 2. With expected improvement
set.seed(1)
res <- spot(x=NULL,funSphere,c(-2,-3),c(1,2),
            control=list(funEvals=15,
                         modelControl=list(target="ei")))
res$xbest
res$ybest

### 3. Use local optimization instead of LHS search
set.seed(1)
res <- spot(,funSphere,c(-2,-3),c(1,2),
            control=list(funEvals=15,
                         modelControl=list(target="ei"),
                         optimizer=optimLBFGSB))
res$xbest
res$ybest

### 4. Use transformed input values
set.seed(1)
f2 <- function(x){2^x}
lower <- c(-100, -100)
upper <- c(100, 100)
transformFun <- rep("f2", length(lower))
res <- spot(x=NULL,funSphere,lower=lower, upper=upper,
             control=list(funEvals=15,
                          modelControl=list(target="ei"),
                          optimizer=optimLBFGSB,
                          transformFun=transformFun))
res$xbest
res$ybest
```

---

spotAlgEs *Evolution Strategy Implementation*

Description

This function is used by optimES as a main loop for running the Evolution Strategy with the given parameter set specified by SPOT.

Usage

```
spotAlgEs(
  mue = 10,
  nu = 10,
  dimension = 2,
  mutation = 2,
  sigmaInit = 1,
  nSigma = 1,
  tau0 = 0,
  tau = 1,
  rho = "bi",
  sel = -1,
  stratReco = 1,
  objReco = 2,
  maxGen = Inf,
  maxIter = Inf,
  seed = 1,
  noise = 0,
  fName = funSphere,
  lowerLimit = -1,
  upperLimit = 1,
  verbosity = 0,
  plotResult = FALSE,
  logPlotResult = FALSE,
  sigmaRestart = 0.1,
  preScanMult = 1,
  globalOpt = NULL,
  ...
)
```

Arguments

mue	number of parents, default is 10
nu	selection pressure. That means, number of offspring (lambda) is mue multiplied with nu. Default is 10
dimension	dimension number of the target function, default is 2
mutation	mutation type, either 1 or 2, default is 1
sigmaInit	initial sigma value (step size), default is 1.0
nSigma	number of different sigmas, default is 1
tau0	number, default is 0.0. tau0 is the general multiplier.
tau	number, learning parameter for self adaption, default is 1.0. tau is the local multiplier for step sizes (for each dimension).

rho	number of parents involved in the procreation of an offspring (mixing number), default is "bi"
sel	number of selected individuals, default is -1
stratReco	Recombination operator for strategy variables. 1: none. 2: dominant/discrete (default). 3: intermediate. 4: variation of intermediate recombination.
objReco	Recombination operator for object variables. 1: none. 2: dominant/discrete (default). 3: intermediate. 4: variation of intermediate recombination.
maxGen	number of generations, stopping criterion, default is Inf
maxIter	number of iterations (function evaluations), stopping criterion, default is 100
seed	number, random seed, default is 1
noise	number, value of noise added to fitness values, default is 0.0
fName	function, fitness function, default is funSphere
lowerLimit	number, lower limit for search space, default is -1.0
upperLimit	number, upper limit for search space, default is 1.0
verbosity	defines output verbosity of the ES, default is 0
plotResult	boolean, asks if results are plotted, default is FALSE
logPlotResult	boolean, asks if plot results should be logarithmic, default is FALSE
sigmaRestart	number, value of sigma on restart, default is 0.1
preScanMult	initial population size is multiplied by this number for a pre-scan, default is 1
globalOpt	termination criterion on reaching a desired optimum value, should be a vector of length dimension (LOCATION of the optimum). Default to NULL, which means it is ignored.
...	additional parameters to be passed on to fName

---

spotCleanup *Clean up*

Description

Remove objects

Usage

```
spotCleanup(control)
```

Arguments

control	list of spot control parameters.

spotControl *spotControl*

Description

Default Control list for spot. This function returns the default controls for the functions spot and spotLoop.

Usage

```
spotControl(dimension = NA)
```

Arguments

dimension	problem dimension, that is, the number of optimized parameters. This parameter is mandatory since v2.8.4.

Details

Control is a list of the settings:

design A function that creates an initial design of experiment. Functions that accept the same parameters, and return a matrix like designLHD or designUniformRandom can be used. Default is designLHD.

designControl A list of controls passed to the control list of the design function. See help of the respective function for details. Default is an empty list.

directOpt A function that is used to optimize after the spot run is finished. Functions that accept the same parameters, and return a matrix like optimNLOPTR or optimDE can be used. Default is optimNLOPTR.

directOptControl A list of controls, which determine whether a direct optimization (exploitation of the final search region) is performed. Default is to run no direct optimization, i.e., directOptControl = list(funEvals = 0)list.

funEvals This is the budget of function evaluations of the direct optimization performed after the SMBO is performed. Default is list(funEvals = 0).

duplicate In case of a deterministic (non-noisy) objective function, this handles duplicated candidate solutions. By default (duplicate = "EXPLORE"), duplicates are replaced by new candidate solutions, generated by random sampling with uniform distribution. If desired, the user can set this to "STOP", which means that the optimization stops and results are returned to the user (with a warning). This may be desirable, as duplicates can be a indicator for convergence, or for a problem with the configuration. In case of noise, duplicates are allowed.

funEvals This is the budget of function evaluations (spot uses no more than funEvals evaluations of fun), defaults to 20.

handleNAsMethod A function that treats NAs if there are any present in the result vector of the objective function. Default: NULL. By default NAs will not be treated.

infillCriterion A function defining an infillCriterion to be used while optimizing a model. Default: NULL. For example check infillExpectedImprovement

model A function that builds a statistical model of the observed data. Functions that accept the same parameters, and return a matrix like buildKriging or buildRandomForest can be used. Default is buildKriging.

modelControl A list of controls passed to the control list of the model function. See help of the respective function for details. Default is an empty list.

multiStart Number of restarts for optimization on the surrrogate model. Default: 1, i.e., no restarts.

noise Boolean, whether the objective function has noise or not. Default is non-noisy, that is, FALSE.

OCBA Boolean, indicating whether Optimal Computing Budget Allocation (OCBA) should be used in case of a noisy objective function or not. OCBA controls the number of replications for each candidate solution. Note, that replicates should be larger than one in that case, and that the initial experimental design (see design) should also have replicates larger one. Default is FALSE.

OCBABudget The number of objective function evaluations that OCBA can distribute in each iteration. Default is 3.

optimizer A function that is used to optimize based on model, finding the most promising candidate solutions. Functions that accept the same parameters, and return a matrix like optimLHD or optimDE can be used. Default is optimLHD.

optimizerControl A list of controls passed to the control list of the optimizer function. See help of the respective function for details. Default is an empty list.

parNames Vector of parameter names of each variable as a string, defaults c("x1", "x2", "x3",..).

plots Whether progress should be tracked by a line plot, default is FALSE

progress Whether progress should be visualized, default is FALSE

replicates The number of times a candidate solution is initially evaluated, that is, in the initial design, or when created by the optimizer. Default is 1.

replicateResult logical. If TRUE, one result is replicated. The result is specified as the lower vector and re-evaluated funEvals times. No model building and optimization is performed, only evaluations on the objective function. Default: FALSE.

returnFullControlList logical. Return the full control list. Can be switched off to save memory/space. Default: TRUE.

seedFun An initial seed for the objective function in case of noise, by default NA. The default means that no seed is set. The user should be very careful with this setting. It is intended to generate reproducible experiments for each objective function evaluation, e.g., when tuning non-deterministic algorithms. If the objective function uses a constant number of random number generations, this may be undesirable. Note, that this seed is by default set prior to each evaluation. A replicated evaluation will receive an incremented value of the seed. Sometimes, the user may want to call external code using random numbers. To allow for that case, the user can specify an objective function (fun), which has a second parameter seed, in addition to first parameter (matrix x). This seed can then be passed to the external code, for random number generator initialization. See end of examples section for a demonstration.

seedSPOT This value is used to initialize the random number generator. It ensures that experiments are reproducible. Default is 1.

subsetSelect A function that selects a subset from a given set of design points. Default is selectAll.

subsetControl A list of controls passed to the control list of the subsetSelect function. See help of the respective function for details. Default is an empty list.

time List with the following time information:

maxTime num Maximum allowed run time (in minutes) for spot or spotLoop. The default value for maxTime (in minutes) is Inf and can be overwritten by the user. The internal value startTime, that is used to control maxTime, will be set by spotFillControlList. Note: maxTime is only an approximate value. It does not affect the directOpt run.

startTime Start time. Will be set in spotFillControlList.

endTime End time.

types Vector of data type of each variable as a string, defaults "numeric" for all variables.

verbosity Integer level specifying how much output should be given by SPOT. 0 (default) ignores warnings of internal optimizers /models. 1 will show warnings and output.

Value

a list

---

spotLoop *Sequential Parameter Optimization Main Loop*

Description

SPOT is usually started via the function spot. However, SPOT runs can be continued (i.e., with a larger budget specified in control$funEvals) by using spotLoop. This is the main loop of SPOT iterations. It requires the user to give the same inputs as specified for spot. Note: control$funEvals must be larger than the value used in the previous run, because it specifies the total number of function evaluations and not the additional number of evalutions.

Usage

```
spotLoop(x, y, fun, lower, upper, control, ...)
```

Arguments

x	(m,n) matrix that contains the known candidate solutions. The SPOT loop is started with these values. Each row represents one n dimensional data point. Each of the m columns represents one optimized parameter.
y	(m,p) matrix that represents observations for each point in x, Each of the m rows represents solutions for one data point.

fun	function that represents the objective function. It should receive a matrix x and return a matrix y. In case the function uses external code and is noisy, an additional seed parameter may be used, see the control$seedFun argument below for details.
lower	is a vector that defines the lower boundary of search space. This determines also the dimension of the problem.
upper	is a vector that defines the upper boundary of search space.
control	is a list with control settings for spot. See spotControl.
...	additional parameters passed to fun.

Value

This function returns a list with:

xbest Parameters of the best found solution (matrix).

ybest Objective function value of the best found solution (matrix).

x Archive of all evaluation parameters (matrix).

y Archive of the respective objective function values (matrix).

count Number of performed objective function evaluations.

msg Message specifying the reason of termination.

modelFit The fit of the last build model, i.e., an object returned by the last call to the function specified by control$model.

Examples

```
## Most simple example: Kriging + LHS + predicted
## mean optimization (not expected improvement)

control <- list(funEvals=20)
res <- spot(,funSphere,c(-2,-3),c(1,2),control)
## now continue with larger budget.
## 5 additional runs will be performed.
control$funEvals <- 25
res2 <- spotLoop(res$x,res$y,funSphere,c(-2,-3),c(1,2),control)
res2$xbest
res2$ybest
```

---

spotPlotErrors *spotPlotErrors*

Description

Visualize the alpha, beta errors and the power of the test

Usage

```
spotPlotErrors(
  alternative = "greater",
  lower = -3,
  upper = 3,
  mu0 = 0,
  mu1 = 1,
  sigma = 1,
  n = NULL,
  xbar = 0,
  alpha = 0.05,
  beta = NULL
)
```

Arguments

alternative	One of greater, less, or two.sided. The greater is the default.
lower	lower limit of the plot
upper	upper limit of the plot
mu0	mean of the null
mu1	mean of the alternative. See also parameter beta.
sigma	standard deviation
n	sample size
xbar	observed mean
alpha	error of the first kind
beta	error 2nd kind. Default NULL. If specified, then parameter mu1 will be ignored and mu1 will be calculated based on beta.

Value

description of return value

Examples

```
spotPlotErrors(lower=490,upper=510,mu0=500,mu1=504,sigma=2.7,n=9,xbar=502.22)
spotPlotErrors(lower=140,upper=155,mu0=150,mu1=148,sigma=10,n=100,xbar=149,alternative="less")
```

spotPlotPower *spotPlotPower*

Description

Plot power

Usage

```
spotPlotPower(y0, y1, alpha = 0.05, add = FALSE, n = NA, rightLimit = 1)
```

Arguments

y0	First input vector
y1	Second input vector
alpha	description of alpha, default value is 0.05
add	Boolean, default value is FALSE
n	number of vector elements that should be evaluated, default value is NA, which means the whole vector
rightLimit	description of rightLimit, default value is 1

Value

description of return value

spotPlotSeverityBasic *spotPlotSeverityBasic*

Description

spotPlotSeverityBasic

Usage

```
spotPlotSeverityBasic(y0, y1, add = FALSE, n = NA, alpha, rightLimit = 1)
```

Arguments

y0	first input vector
y1	second input vector
add	default value is FALSE
n	default value is NA, which means length of y0 will be used for n
alpha	description
rightLimit	description of rightLimit, default value is 1

Value

description of return value

Examples

```
### Example from D G Mayo and A Spanos.
### Severe Testing as a Basic Concept in a NeymanPearson Philosophy of Induction.
### British Journal for the Philosophy of Science, 57:323357, 2006. (fig 2):
x0 <- 12.1
mu1 <- seq(11.9,13,0.01)
n <- 100
sigma <- 2
alpha <- 0.025
plot(mu1, spotSeverityBasic(x0, mu1, n, sigma, alpha), type = "l", ylim=c(0,1), col="blue")
abline(h=0)
abline(h=1)
 abline(h=0.95)
abline(v=12.43)
### plot power:
mu0 <- 12
points(mu1, spotPower(alpha, mu0, mu1, n, sigma), type = "l", ylim=c(0,1), col="green")
abline(v=12.72)
```

---

spotPlotTest *spotPlotTest*

Description

Visualize test result, errors, and severity

Usage

```
spotPlotTest(
  alternative = "greater",
  lower = -3,
  upper = 3,
  mu0 = 0,
  mu1 = 1,
  sigma = 1,
  n = NULL,
  xbar = 0,
  alpha = 0.05,
  beta = NULL
)
```

Arguments

alternative	One of greater, less, or two.sided. Full plots are currently implemented for less, which is the default.
lower	lower limit of the plot
upper	upper limit of the plot
mu0	mean of the null
mu1	mean of the alternative. See also parameter beta.
sigma	standard deviation
n	sample size
xbar	observed mean
alpha	error of the first kind
beta	error 2nd kind. Default NULL. If specified, then parameter mu1 will be ignored and mu1 will be calculated based on beta.

Value

description of return value

Examples

```
spotPlotTest(lower=490, upper=510, mu0=500, mu1=504, sigma=2.7, n=9, xbar=502.22, alpha=0.025)
## The following two plots should be nearly identical:
spotPlotTest(lower=490, upper=510, mu0=500, sigma=2.7, n=9, xbar=502.22, alpha=0.025, beta=0.2)
spotPlotTest(lower=490, upper=510, mu0=500, mu1=502.5215, sigma=2.7, n=9, xbar=502.22, alpha=0.025)
```

---

spotPower *spotPower*

Description

Calculate power

Usage

```
spotPower(alpha, mu0, mu1, n, sigma)
```

Arguments

alpha	description of alpha
mu0	description of mu0
mu1	description of mu1
n	vector length
sigma	standart deviation

Value

description of return value

`spotSeverity` *spotSeverity*

Description

spotSeverity

Usage

```
spotSeverity(xbar, mu0, mu1, n, sigma, alpha, tdist = FALSE, paired = TRUE)
```

Arguments

`xbar`	sample mean value
`mu0`	mean value of the null hypothesis (usually referred to as H0)
`mu1`	mean value of the alternative hypothesis (usually referred to as H1)
`n`	sample size in each arm, e.g., if 20 samples are available, then `n=10` regardless whether the samples are paired/blocked (`paired=TRUE`) or independent (`paired=FALSE`). Degrees of freedom will be modified internally according to the setting of the `paired` argument.
`sigma`	sample s.d. Will be used to determine s.d. of the differences (if `paired==TRUE`) or s.d. of the pooled s.d (if `paired==FALSE`).
`alpha`	probability of a type I error, given H0 is true
`tdist`	logical. Use Student t Distribution. Default: FALSE
`paired`	logical. Paired (blocked) data. Default: TRUE

Value

an object of class `"spotSeverity"`, with a `summary` method and a `print` method.

Examples

```
s0 <- spotSeverity(xbar=0.4, mu0=0.0, mu1=0.6, n=25, sigma=1, alpha=0.03)
print(s0)
s1 <- spotSeverity(xbar=0.4, mu0=0.6, mu1=0.6, n=25, sigma=1, alpha=0.03)
print(s1)
s2 <- spotSeverity(xbar=0, mu0=0.6, mu1=0.6, n=25, sigma=1, alpha=0.03)
print(s2)

## Example from Mayo, p345
spotSeverity(xbar=90, mu0=0, mu1= 200, n=200, sigma = 450, alpha = 0.025,
paired = FALSE, tdist = FALSE)
```

```
## Example from Vena02a to compare with results from t.test()
## library("BHH2")
## data(shoes.data)
## A <- shoes.data$matA
## B <- shoes.data$matB
 A <- c(13.2, 8.2, 10.9, 14.3, 10.7, 6.6, 9.5, 10.8, 8.8, 13.3)
 B <- c(14, 8.8, 11.2, 14.2, 11.8, 6.4, 9.8, 11.3, 9.3, 13.6)
t.paired <- t.test(x = A, y = B, var.equal = TRUE, paired = TRUE,
alternative = "greater",  conf.level = 0.95)
xbar <- mean(A-B)
n <- length(A)
sigma <- sd(A-B)
s.paired <- spotSeverity(xbar=xbar,mu0=0, mu1= 1, n=n, sigma = sigma,
alpha = 0.025, tdist = TRUE)
```

`spotSeverityBasic` *spotSeverityBasic*

Description

spotSeverityBasic

Usage

```
spotSeverityBasic(x0, mu1, n, sigma, alpha)
```

Arguments

`x0`	sample mean value
`mu1`	description
`n`	description
`sigma`	description
`alpha`	description

Value

description of return value

sring *sring*

Description

simple elevator simulator

Usage

```
sring(x, opt = list(), ...)
```

Arguments

x	perceptron weights
opt	list of optional parameters, e.g.,
	nElevators number of elevators
	probNewCustomer probability pf a customer arrival
	nIterations Number of itertions
	randomSeed random seed
...	additional parameters

Value

fitness

Examples

```
set.seed(123)
nStates = 6
nElevators = 2
sigma = 1
x = matrix( rnorm(n = 2*nStates, 1, sigma), 1,)
sring(x, opt = list(nElevators=nElevators,
                    nStates= nStates) )
```

sringRes1 *S-Ring Simulation Data*

Description

A data set based on evaluations of the funCosts function. The corresponding code can be found in the vignette SPOTVignetteElevator

Usage

```
sringRes1
```

Format

A data frame with 20 obs. of 3 variables:

y num 10 10 10 10 10 ...

sigma num 0.1 0.1 0.1 0.1 0.1 1 1 1 1 1 ..

ne num 5 5 5 5 5 5 5 5 5 5 ...

---

sringRes2 *S-Ring Simulation Data*

Description

A data set based on evaluations of the `funCosts` function. Second experiment (extension of the first design) The corresponding code can be found in the vignette SPOTVignetteElevator

Usage

```
sringRes2
```

Format

A data frame with 22 obs. of 3 variables:

y num 10 10 10 10 10 ...

sigma num 0.1 0.1 0.1 0.1 0.1 1 1 1 1 1 ..

ne num 5 5 5 5 5 5 5 5 5 5 ...

---

sringRes3 *S-Ring Simulation Data*

Description

A data set based on evaluations of the `funCosts` function. Second experiment (extension of the first design) The corresponding code can be found in the vignette SPOTVignetteElevator

Usage

```
sringRes3
```

Format

A data frame with 27 obs. of 3 variables:

y num 1e+07 1e+07 1e+07 1e+07 1e+07 ...

sigma num 0.1 0.1 0.1 0.1 0.1 1 1 1 1 1 ...

ne num 5 5 5 5 5 5 5 5 5 5 ...

---

thetaNugget *thetaNugget*

Description

get theta (distance, lengthscale) and nugget (noise) parameters gradient

Usage

```
thetaNugget(par, X, Y)
```

Arguments

par	parameter vector. First dim(x) entries are theta values, last entry is nugget parameter.
X	x coordinates
Y	y values at x

Value

negLogLikelihood

---

thetaNuggetGradient *thetaNuggetGradient*

Description

get theta (distance, lengthscale) and nugget (noise) parameters gradient

Usage

```
thetaNuggetGradient(par, X, Y)
```

Arguments

par	parameter vector. First dim(x) entries are theta values, last entry is nugget parameter.
X	x coordinates
Y	y values at x

transformX *Transform input*

Description

Transform input variables

Usage

```
transformX(xNat = NA, fn = vector())
```

Arguments

xNat	matrix with natural variables. Default: NA.
fn	vector of transformation functions names (char). Default: Empty vector (vector()).

Value

matrix of transformed parameters

Examples

```
f2 <- function(x){2^x}
fn <- c("identity", "exp", "f2")
xNat <- diag(3)
transformX(xNat, fn)

fn <- append(fn, c("sin", "cos", "tan"))
xNat <- cbind(xNat, xNat)
transformX(xNat, fn)
```

vmessage *formatted output dependent on verbosity*

Description

Combine sprintf and writeLines to generate formatted output

Usage

```
vmessage(verbosity, text, value)
```

Arguments

verbosity	verbosity level
text	output to be printed
value	value to be printed

Examples

```
x <- 123
vmessage(1, "value of x:" , x)
```

`wrapBatchTools` *wrapBatchTools*

Description

Wrap a given objective function to be evaluated via the batchtools package and make it accessible for SPOT.

Usage

```
wrapBatchTools(
  fun,
  reg = NULL,
  clusterFunction = batchtools::makeClusterFunctionsInteractive(),
  resources = NULL
)
```

Arguments

`fun`	function to wrap
`reg`	batchtools registry, if none is provided, then one will be created automatically
`clusterFunction`	batchtools clusterFunction, default: makeClusterFunctionsInteractive()
`resources`	resource list that is passed to batchtools, default NULL

Value

callable function for SPOT

wrapFunction *Function Evaluation Wrapper*

Description

This is a simple wrapper that turns a function of type y=f(x), where x is a vector and y is a scalar, into a function that accepts and returns matrices, as required by spot. Note that the wrapper essentially makes use of the apply function. This is effective, but not necessarily efficient. The wrapper is intended to make the use of spot easier, but it could be faster if the user spends some time on a more efficient vectorization of the target function.

Usage

```
wrapFunction(fun)
```

Arguments

fun	the function y=f(x) to be wrapped, with x a vector and y a numeric

Value

a function in the style of y=f(x), accepting and returning a matrix

Examples

```
## example function
branin <- function (x) {
  y <- (x[2]  - 5.1/(4 * pi^2) * (x[1] ^2) + 5/pi * x[1]  - 6)^2 +
    10 * (1 - 1/(8 * pi)) * cos(x[1] ) + 10
  y
}
## vectorize / wrap
braninWrapped <-wrapFunction(branin)
## test original
branin(c(1,2))
branin(c(2,2))
branin(c(2,1))
## test wrapped
braninWrapped(matrix(c(1,2,2,2,2,1),3,2,byrow=TRUE))
```

wrapFunctionParallel *Parallelized Function Evaluation Wrapper*

Description

This is a simple wrapper that turns a function of type `y=f(x)`, where x is a vector and y is a scalar, into a function that accepts and returns matrices, as required by `spot`. While doing so, the wrapper will use the parallel package in order to parallelize the execution of each function evaluation. This function will create a computation cluster if no cluster is specified and there is no default cluster setup!

Usage

```
wrapFunctionParallel(fun, cl = NULL, nCores = NULL)
```

Arguments

`fun`	the function that shall be evaluated in parallel
`cl`	Optional, an existing computation cluster
`nCores`	Optional, amount of cores to use for creating a new computation cluster. Default is all cores.

Value

numeric vector, result of the parallelized evaluation

wrapSystemCommand *wrapSystemCommand*

Description

Optimize parameters for a script that is accessible via Command Line

Usage

```
wrapSystemCommand(systemCall)
```

Arguments

`systemCall`	String that calls the command line script.

Value

callable function for SPOT

Examples

```
# exampleScriptLocation <- system.file("consoleCallTrialScript.R",package = "SPOT")
# f <- wrapSystemCommand(paste("$(R_HOME)/bin/Rscript", exampleScriptLocation))
# spot(,f,c(1,1),c(100,100))
```

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