# Package 'rCMA'

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**Type** Package

**Title** R-to-Java Interface for 'CMA-ES'

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**Description** Tool for providing access to the Java version 'CMAEvolutionStrategy' of Nikolaus Hansen. 'CMA-ES' is the Covariance Matrix Adaptation Evolution Strategy, see https://www.lri.fr/~hansen/cmaes_inmatlab.html#java.

**License** GPL (>= 3)

**Depends** R (>= 2.14.0),

**Suggests** rJava

**Collate** 'rCMA.R' 'cmaGetters.R' 'cmaEvalMeanX.R'

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rCMA-package *R interface to the Java CMA-ES of Niko Hansen*

## Description

CMA-ES R-to-Java interface

## Details

| | |
|---|---|
| Package: | rCMA |
| Type: | Package |
| Version: | 1.1 |
| Date: | 2015-04-30 |
| License: | GPL (>= 3) |
| LazyLoad: | yes |

rCMA is a package to perform CMA-ES optimization, using the *Java* implementation by Niko Hansen [Hansen2009].
CMA-ES [HansOst96, Hansen13] is the Covariance Matrix Adapting Evolutionary Strategy for numeric black box optimization.
The main features of rCMA are:

1. Abiltiy to start the Java CMA-ES optimization with fitness functions defined in R.
2. Constraint handling: Arbitrary constraints can be incorporated, see function parameter `isFeasible` in `cmaOptimDP`.
3. Extensibility: Full access to all methods of the Java class `CMAEvolutionStrategy` through package `rJava`. New methods can be added easily. See the documentation of `cmaEvalMeanX` for further details, explanation of JNI types and a full example.
4. Test and Debug: The access of Java methods from R allows for easy debugging and test of programs using `CMAEvolutionStrategy` through R scripts without the necessity to change the underlying JAR file.

The main entry point functions are `cmaNew`, `cmaInit` and `cmaOptimDP`.

Note: To install `rJava` properly on some Unix systmes, it might be necessary to issue as root the command `R CMD javareconf` once, or, as normal user to issue the command `R CMD javareconf -e` prior to installing package `rJava` or prior to loading library `rJava`.

## Author(s)

Wolfgang Konen (<wolfgang.konen@fh-koeln.de>)

## References

[HansOst96] Hansen, N. and Ostermeier, A.: Adapting arbitrary normal mutation distributions in evolution strategies: The covariance matrix adaptation. In Proceedings of the 1996 IEEE International Conference on Evolutionary Computation, pp. 312-317, 1996. PDF.

[Hansen09] https://www.lri.fr/~hansen/javadoc Nikolaus Hansen: Javadoc for CMA-ES Java package fr.inria.optimization.cmaes, 2009.
[Hansen13] https://www.lri.fr/~hansen/cmaesintro.html Nikolaus Hansen: The CMA Evolution Strategy Web Page, 2013.
[Urbanek13] http://cran.r-project.org/web/packages/rJava Urbanek, S.: rJava: Low-level R to Java interface, 2013.
[Oracle14] http://docs.oracle.com/javase/7/docs/technotes/guides/jni/spec/jniTOC.html Oracle: The Java Native Interface. Programmer's Guide and Specification, 2014.

---

`cmaCalcFitness` *Calculate the fitness of a population.*

---

## Description

The population is usually obtained by `cmaSamplePopulation`.

## Usage

```
cmaCalcFitness(cma, popR, fitFunc)
```

## Arguments

| | |
|---|---|
| `cma` | CMA-ES Java object, already initialized with `cmaInit` |
| `popR` | a (`dimension x popSize`) matrix from `cmaSamplePopulation` |
| `fitFunc` | a function to be minimized. Signature: accepts a vector `x`, returns a `double`. |

## Value

`fitness`, a vector of length `cmaGetPopulationSize(cma)` with the fitness of each individuum

## Author(s)

Wolfgang Konen, FHK, 2013

## See Also

`cmaSamplePopulation`, `cmaUpdateDistribution`, `cmaNew`

## Examples

```
cma <- cmaNew();
   cmaInit(cma,dimension=2,initialX=1.5);
   popR <- cmaSamplePopulation(cma);
   fitFunc <- function(x) {sum(x*x)};
   fitness <- cmaCalcFitness(cma,popR,fitFunc);
   cmaUpdateDistribution(cma,fitness);
```

cmaEvalMeanX *Evaluate the meanX of the current population.*

## Description

After executing cmaOptimDP, there is a current population and a best-ever solution. Evaluate for the mean of the current population whether it is feasible and whether the mean is an even better solution. If so, update the best-ever solution.

## Usage

```
cmaEvalMeanX(cma, fitFunc, isFeasible = function(x) TRUE)
```

## Arguments

| | |
|---|---|
| cma | CMA-ES Java object, already initialized with cmaInit |
| fitFunc | a function to be minimized. Signature: accepts a vector x, returns a double. |
| isFeasible | [function(x){TRUE}] a Boolean function checking the feasibility of the vector x. The default is to return always TRUE. |

## Details

The code of this function is also instructive as a full example for the extensibility of the rJava interface to CMA-ES. See the full code in demo/demoEvalMeanX. Some example rJava-calls are:

```
rJava::.jcall(cma,"[D","getMeanX");
bestSolutionObj =
 rJava::.jcall(cma,"Lfr/inria/optimization/cmaes/CMASolution;","setFitnessOfMeanX",fitFunc(meanX
rJava::.jcall(bestSolutionObj,"J","getEvaluationNumber");
```

Every direct method of classes in the CMA-ES Java package cmaes (see [Hansen09] for the complete Javadoc and [Hansen13] for an overview on CMA-ES in total) can be accessed with the .jcall-mechanism of the rJava R package:

```
rJava::.jcall(obj,returnType,method,...)
```

where ... stands for the calling parameter(s) of method.
returnType is a string following the JNI type convention (see, e.g. [Oracle14])

| Field Descriptor | Java Language Type |
|---|---|
| Z | boolean |
| C | char |
| I | int |
| J | long |
| F | float |
| D | double |
| [I | int[] |

| | |
|---|---|
| [[D | double[][] |
| Ljava/langString; | java.lang.String |
| S | java.lang.String |
| T | short |

(Note: (a) the terminating `";"` in `"Ljava/langString;"` (!) and (b) `"S"` is a short hand for `"Ljava/langString;"` and `"T"` is the re-mapped code for `short`. )

The calling parameters in `...` have to be matched exactly. In R, numeric vectors are stored as `doubles`, so the calling syntax

```
bestSolutionObj = .jcall(cma,rType,"setFitnessOfMeanX",fitFunc(meanX));
```

is just right for the Java method `setFitnessOfMeanX(double[])` . In other cases, the calling R variable `x` has to be cast explicitly:

| Cast | Java Language Type |
|---|---|
| .jbyte(x) | byte |
| .jchar(x) | char |
| as.integer(x) | int |
| .jlong(x) | long |
| .jfloat(x) | float |

## Value

`bestSolution`, a list with entries:

| | |
|---|---|
| `bestX` | a vector of length `dimension` containing the best-ever solution, including `meanX` |
| `meanX` | a vector of length `dimension` containing the mean of the current (last) population in `cma` |
| `bestFitness` | the best-ever fitness value, including the evaluation of meanX |
| `bestEvalNum` | the function evaluation count where `bestFitness` occured |
| `lastEvalNum` | the total function evaluation count. If `bestEvalNum==lastEvalNum` then the best-ever fitness occured in the evaluation of `meanX`. |

## Author(s)

Wolfgang Konen, FHK, 2013-2015

## References

[Hansen09] https://www.lri.fr/~hansen/javadoc Nikolaus Hansen: Javadoc for CMA-ES Java package fr.inria.optimization.cmaes, 2009.
[Hansen13] https://www.lri.fr/~hansen/cmaesintro.html Nikolaus Hansen: The CMA Evolution Strategy, 2013.
[Oracle14] http://docs.oracle.com/javase/7/docs/technotes/guides/jni/spec/jniTOC.

html Oracle: The Java Native Interface. Programmer's Guide and Specification. Chapter 3 (JNI types), Sec. 'Type Signatures', 2014.

## See Also

cmaInit, cmaOptimDP

## Examples

```
## Not run:
   ## just to show the syntax, without calling cmaOptimDP
   fitFunc <- function(x) {  sum(x*x); }
   isFeasible <- function(x) {  TRUE;  }
   cma <- cmaNew(propFile="CMAEvolutionStrategy.properties");
   cmaInit(cma,dimension=2,initialX=1.5);
   bestSolution=cmaEvalMeanX(cma,fitFunc,isFeasible);
   str(bestSolution);

## End(Not run)
```

---

# cmaInit *Initialize a CMA-ES Java object.*

---

## Description

Initialize a CMA-ES Java object.

## Usage

```
cmaInit(cma, seed = NULL, dimension = NULL, initialX = NULL,
  initialStandardDeviations = NULL)
```

## Arguments

| | |
|---|---|
| cma | CMA-ES Java object, as created by cmaNew |
| seed | [NULL] if not NULL, set the seed to the given value |
| dimension | [NULL] if not NULL, overwrite the dimension setting from propFile (cmaNew) |
| initialX | [NULL] if not NULL, overwrite the initialX setting from propFile (cmaNew). initialX can be a double or a double vector of length dimension. |
| initialStandardDeviations | [NULL] if not NULL, overwrite the initialStandardDeviations setting from propFile cmaNew. initialStandardDeviations can be a double or a double vector of length dimension. |

## Value

fitness, a vector of 0's with the length of the intended population.

### Note

As a side effect, the CMA-ES Java object cma of class CMAEvolutionStrategy is transferred into an augmented state. As a second side effect, the population size is set to

$$\lambda = 4 + 3floor(ln(n))$$

where $n$ =dimension.

### Author(s)

Wolfgang Konen, FHK, 2013

### See Also

cmaNew, cmaOptimDP

### Examples

```
cma <- cmaNew();
   cmaInit(cma,seed=42,dimension=2,initialX=1.5);
```

---

## cmaNew *Create a new CMA-ES Java object.*

---

### Description

Create a new CMA-ES Java object.

### Usage

```
cmaNew(propFile = NULL)
```

### Arguments

| | |
|---|---|
| propFile | [NULL] filename of a file with property settings. If NULL, read file CMAEvolutionStrategy.properties from the package directory (find.package("rCMA")) |

### Value

the new CMA-ES Java object of class CMAEvolutionStrategy, which has as additional attribute props, the Java Properties object as read from propFile.

### Note

The default properties file can be found in CMAEvolutionStrategy.properties. A read-only copy can be inspected by browsing to "Index" (of package rCMA), then "Overview of user guides ...".
It allows to set more parameter, especially more stop conditions.

## Author(s)

Wolfgang Konen, FHK, 2013

## See Also

cmaInit

## Examples

```
## show how element initialX can be inferred from attribute props:
  ## (see  cmaEvalMeanX-documentation for further details on .jcall and its argument "S")
   cma <- cmaNew();
   props <- attr(cma,"props");
   initialX = rJava::.jcall(props,"S","getProperty","initialX");
   print(initialX);
```

---

cmaOptimDP *Perform a CMA-ES optimization with constraints (DP).*

---

## Description

The optimization uses DP (death penalty) for handling constraint violations: Each time an infeasible individual is encountered, it is thrown away and a new individual is resampled from the CMA distribution.

## Usage

```
cmaOptimDP(cma, fitFunc, isFeasible = function(x) {     TRUE },
  maxDimPrint = 5, iterPrint = 10, verbose = 2)
```

## Arguments

| | |
|---|---|
| cma | CMA-ES Java object, already initialized with cmaInit |
| fitFunc | a function to be minimized. Signature: accepts a vector x, returns a double. |
| isFeasible | [function(x){TRUE}] a Boolean function checking the feasibility of the vector x. The default is to return always TRUE. |
| maxDimPrint | [5] how many dimensions of vector x to print in diagnostic output |
| iterPrint | [10] after how many iterations should diagnostic output be printed? |
| verbose | [2] possible values are 0 (no output), 1, 2 (much output) |

## Details

This functions loops through iterations (generations) until a stop condition is met: In each iteration, a population is sampled (infeasible individuals are replaced via Java function `resampleSingle`), its fitness vector is evaluated and the CMA distribution is updated according to this fitness vector.

Every `iterPrint` generations a one-line diagnostic output of the form

```
iter  fitness | x1 x2 ... xp
```

is printed where `fitness` is the current best value of the fitness function to be minimized and `x1 x2 ... xp` are the first `maxDimPrint` dimensions of the corresponding best point in input space.

## Value

`res`, a list with diagnostic output from the optimization run:

| | |
|---|---|
| `sMsg` | a string vector with all console output from the optimization run. To print it, use: `cat(sMsg)` or `for (x in sMsg) cat(x)` |
| `bestX` | vector of length `dimension` with the best-ever solution X |
| `bestFitness` | the corresponding best-ever fitness |
| `bestEvalNum` | the fitness function evaluation number which gave this best-ever result |
| `nIter` | number of iterations |
| `fitnessVec` | vector of length `nIter`: the best fitness after each iteration |
| `xMat` | (`nIter x dimension`)-matrix: `xMat[i,]` is the best solution X after iteration `i` |
| `cfe` | number of constraint function evaluations (`isFeasible`) |
| `ffe` | number of fitness function evaluations (`fitFunc`) |

## Note

If your fitness function depends on other parameters besides `x`, then encapsulate it in a new function `fitFunc` at a place where the other parameters are accessible and rely on R's mechanism to locate the other parameters in the environment surrounding `fitFunc`:

```
par1 <- someObject;


fitFunc <- function(x) {  myFuncWithOtherPars(x,par1); }
```

## Author(s)

Wolfgang Konen, FHK, 2013-2015

## See Also

`cmaNew`, `cmaInit`

## Examples

```
## demo/demoCMA2.R: demo usage of package rCMA.
##
## After doing the unconstrained sphere (as in demoCMA1.r, for later reference in plot),
## the constrained sphere problem TR2 is solved.
## The problem TR2 has in addition to the fitness function 'sphere' the constraint function
## 'above the hyperplane sum_i(x_i) = n', where n is the input space dimension.
## The constrained optimum is at (1,...,1) and it has the value fTarget2=n.
##
## Note that in this second case, the optimimum lies exactly at the boundary
## of the feasible region: res2$bestX=c(1,...,1).
##
## This script does exactly the same as class CMAExampleConstr in cma_jAll.jar,
## but it allows to define the functions fitFunc and isFeasible on the R side.
## They can be replaced by arbitrary other R functions, which may depend on other
## R variables as well.
##
## The constraint handling approach is a very simple one: death penalty, i.e. if we get an
## infeasible individual, it is immediately discarded and a new one is drawn from the distribution.
## (This approach will run into trouble if the current distribution does not allow to reach any
## feasible solutions.)
##
library(rCMA)
fitFunc <- function(x) {  sum(x*x); }
isFeasible <- function(x) {  (sum(x) - length(x)) >= 0;  }
n = 2;

cma <- cmaNew(propFile="CMAEvolutionStrategy.properties");
cmaInit(cma,seed=42,dimension=n,initialX=1.5, initialStandardDeviations=0.2);
res1 = cmaOptimDP(cma,fitFunc,iterPrint=30);

cma <- cmaNew(propFile="CMAEvolutionStrategy.properties");
cmaInit(cma,seed=42,dimension=n,initialX=1.5, initialStandardDeviations=0.2);
res2 = cmaOptimDP(cma,fitFunc,isFeasible,iterPrint=30);

fTarget =c(0,n);
plot(res1$fitnessVec-fTarget[1],type="l",log="y",xlim=c(1,max(res1$nIter,res2$nIter))
    ,xlab="Iteration",ylab="Distance to target fitness");
lines(res2$fitnessVec-fTarget[2],col="red");
legend("topright",legend=c("TR2","sphere"),lwd=rep(1,2),col=c("red","black"))
str(res2);

bestSolution=rCMA::cmaEvalMeanX(cma,fitFunc,isFeasible);
str(bestSolution);
```

---

`cmaSamplePopulation` *Sample a population from the current CMA-ES distribution.*

---

## Description

The population size is given by `cmaGetPopulationSize(cma)`. It can be either set manually with `cmaSetPopulationSize(cma,p)`, prior to `cmaInit(cma)`, or CMA-ES will use the default population size
`popSize = 4 + 3*log(dimension)`.

## Usage

```
cmaSamplePopulation(cma)
```

## Arguments

| | |
|---|---|
| `cma` | CMA-ES Java object, already initialized with `cmaInit` |

## Value

`popR`, a (`dimension x popSize`) matrix with `popR[,1]` being the first individuum in the population.
`dimension = cmaGetDimension(cma)`
`popSize = cmaGetPopulationSize(cma)`

## Author(s)

Wolfgang Konen, FHK, 2013

## See Also

`cmaUpdateDistribution`, `cmaNew`

## Examples

```
cma <- cmaNew();
   cmaInit(cma,dimension=2,initialX=1.5);
   popR <- cmaSamplePopulation(cma);
```

---

`cmaSetDimension` *rCMA Getters and Setters.*

---

## Description

Get or set various elements of CMA-ES Java object `cma`.

`cmaSetDimension` sets the problem dimension (only prior to `cmaInit`)
`cmaGetDimension` returns the problem dimension
`cmaSetPopulationSize` sets the population size (only prior to `cmaInit`)
`cmaGetPopulationSize` returns the population size
`cmaSetInitialX` set the mean vector for the initial population (only prior to `cmaInit`)

cmaGetInitialX returns the mean vector for the initial population
cmaSetCountEval sets the counter for fitness function evaluations (only prior to cmaInit)
cmaGetCountEval returns the counter for fitness function evaluations

## Usage

```
cmaSetDimension(cma, i)

cmaGetDimension(cma)

cmaSetPopulationSize(cma, i)

cmaGetPopulationSize(cma)

cmaSetInitialX(cma, initialX)

cmaGetInitialX(cma)

cmaSetCountEval(cma, p)

cmaGetCountEval(cma)
```

## Arguments

| | |
|---|---|
| cma | CMA-ES Java object, created with cmaNew |
| i | a parameter of type integer |
| initialX | either a double or a double vector of length cmaGetDimension |
| p | a parameter of type long |

## Value

none for the setters, the requested element(s) for the getters

## See Also

cmaSetStopFitness, cmaNew, cmaInit

---

# cmaSetStopFitness *rCMA Stop Conditions.*

---

## Description

Set various stop conditions of CMA-ES Java object cma (only prior to cmaInit).

cmaSetStopFitness sets the stop condition: fitness function below d (default: DOUBLE.MinValue)
cmaSetStopMaxFunEvals sets the stop condition: max number of fitness function evaluations
cmaSetStopTolFun sets the stop condition: delta of fitness function below d (default: 1e-12)

### Usage

```
cmaSetStopFitness(cma, d)

cmaSetStopMaxFunEvals(cma, p)

cmaSetStopTolFun(cma, d)
```

### Arguments

| | |
|---|---|
| cma | CMA-ES Java object, created with cmaNew |
| d | a parameter of type double |
| p | a parameter of type long |

### Note

If your fitness can become negative, you need to set `cmaSetStopFitness` to a value different from the default to prevent premature stopping.

The properties file (read by cmaNew) can be used to set further stop conditions. If they are not set, the following defaults are active:

| name | default setting | meaning |
|---|---|---|
| stopTolFunHist | 1e-13 | similar to stopTolFun, see CMA-ES Javadoc for details |
| stopTolX | 0.0 | stop if seacrh steps become smaller than stopTolX |
| stopTolXfactor | 0.0 | stop if search steps become smaller than stopTolXFactor * initial step size |
| stopMaxIter | +Inf | stop if number of iterations (generations) are greater |

### See Also

cmaSetDimension, cmaNew, cmaInit

---

## cmaUpdateDistribution *Update CMA-ES distribution with the fitness vector of the last population.*

---

### Description

Update CMA-ES distribution with the fitness vector of the last population.

### Usage

```
cmaUpdateDistribution(cma, fitness)
```

### Arguments

| | |
|---|---|
| cma | CMA-ES Java object, already initialized with cmaInit |
| fitness | vector of length cmaGetPopulationSize(cma) with the fitness of each individuum |

## Note

As a side effect, the CMA-ES Java object cma of class `CMAEvolutionStrategy` is augmented.

## Author(s)

Wolfgang Konen, FHK, 2013

## See Also

`cmaSamplePopulation`, `cmaNew`, `cmaOptimDP`

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