Package 'mvQuad'

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Title Methods for Multivariate Quadrature

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Description Provides methods to construct multivariate grids, which can be used for multivariate quadrature. This grids can be based on different quadrature rules like Newton-Cotes formulas (trapezoidal-, Simpson's- rule, ...) or Gauss quadrature (Gauss-Hermite, Gauss-Legendre, ...). For the construction of the multidimensional grid the product-rule or the combination- technique can be applied.

URL https://github.com/weiserc/mvQuad/

License GPL-3

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`mvQuad-package` *Methods for multivariate Quadrature (numerical integration)*

Description

This package provides methods to construct multivariate grids, which can be used for multivariate quadrature. This grids can be based on different quadrature rules like Newton-Cotes formulas (trapezoidal-, Simpson-rule, ...) or Gauss-Quadrature (Gauss-Hermite, Gauss-Legendre, ...). For the construction of the multidimensional grid the product-rule or the combination-technique can be applied.

Details

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References

Philip J. Davis, Philip Rabinowitz (1984): Methods of Numerical Integration

F. Heiss, V. Winschel (2008): Likelihood approximation by numerical integration on sparse grids, Journal of Econometrics

H.-J. Bungartz, M. Griebel (2004): Sparse grids, Acta Numerica

Peter Jaeckel (2005): A note on multivariate Gauss-Hermite quadrature

Examples

```
myGrid <- createNIGrid(dim=2, type="GLe", level=5)
rescale(myGrid, domain=rbind(c(-1,1),c(-1,1)))
```

```
print(myGrid)
plot(myGrid, col="blue")
myFun <- function(x){
   1 - x[,1]^2 * x[,2]^2
}
quadrature(myFun, myGrid)
```

---

copyNIGrid *copies an NIGrid-object*

Description

`copyNIGrid` copies an NIGrid-object

Usage

```
copyNIGrid(object1, object2 = NULL)
```

Arguments

`object1`	original NIGrid-object
`object2`	destination; if NULL `copyNIGrid` returns a NIGrid-object otherwise the `object2` will be overwritten.

Value

Returns a NIGrid-object or NULL

Examples

```
myGrid <- createNIGrid(dim=2, type="GHe", level=5)
myGrid.copy <- copyNIGrid(myGrid)
```

---

createNIGrid *creates a grid for numerical integration.*

Description

`createNIGrid` Creates a grid for multivariate numerical integration. The Grid can be based on different quadrature- and construction-rules.

Usage

```
createNIGrid(dim = NULL, type = NULL, level = NULL,
  ndConstruction = "product", level.trans = NULL)
```

Arguments

- `dim` number of dimensions
- `type` quadrature rule (see Details)
- `level` accuracy level (typically number of grid points for the underlying 1D quadrature rule)
- `ndConstruction` character vector which denotes the construction rule for multidimensional grids.
  - `product` for product rule, returns a "full grid" (default)
  - `sparse` for combination technique, leads to a regular "sparse grid".
- `level.trans` logical variable denotes either to take the levels as number of grid points (FALSE = default) or to transform in that manner that number of grid points = 2^(levels-1) (TRUE). Alternatively `level.trans` can be a function, which takes (n x d)-matrix and returns a matrix with the same dimensions (see the example; this feature is particularly useful for the 'sparse' construction rule, to account for different importance of the dimensions).

Details

The following quadrature rules are supported (build-in).

- `cNC1, cNC2, ..., cNC6` closed Newton-Cotes Formula of degree 1-6 (1=trapezoidal-rule; 2=Simpson's-rule; ...), initial interval of integration: [0, 1]
- `oNC0, oNC1, ..., oNC3` open Newton-Cote Formula of degree 0-3 (0=midpoint-rule; ...), initial interval of integration: [0, 1]
- `GLe, GKr` Gauss-Legendre and Gauss-Kronrod rule for an initial interval of integration: [0, 1]
- `nLe` nested Gauss-Legendre rule for an initial interval of integration: [0, 1] (Knut Petras (2003). Smolyak cubature of given polynomial degree with few nodes for increasing dimension. Numerische Mathematik 93, 729-753)
- `GLa` Gauss-Laguerre rule for an initial interval of integration: [0, INF)
- `GHe` Gauss-Hermite rule for an initial interval of integration: (-INF, INF)
- `nHe` nested Gauss-Hermite rule for an initial interval of integration: (-INF, INF) (A. Genz and B. D. Keister (1996). Fully symmetric interpolatory rules for multiple integrals over infinite regions with Gaussian weight." Journal of Computational and Applied Mathematics 71, 299-309)
- `GHN`, `nHN` (nested) Gauss-Hermite rule as before but weights are multiplied by the standard normal density $(\hat{(w)}_i = w_i * \phi(x_i))$.
- `Leja` Leja-Points for an initial interval of integration: [0, 1]

The argument `type` and `level` can also be vector-value, different for each dimension (the later only for "product rule"; see examples)

Value

Returns an object of class 'NIGrid'. This object is basically an environment containing nodes and weights and a list of features for this special grid. This grid can be used for numerical integration (via `quadrature`)

References

Philip J. Davis, Philip Rabinowitz (1984): Methods of Numerical Integration

F. Heiss, V. Winschel (2008): Likelihood approximation by numerical integration on sparse grids, Journal of Econometrics

H.-J. Bungartz, M. Griebel (2004): Sparse grids, Acta Numerica

See Also

`rescale`, `quadrature`, `print`, `plot` and `size`

Examples

```
## 1D-Grid --> closed Newton-Cotes Formula of degree 1 (trapeziodal-rule)
myGrid <- createNIGrid(dim=1, type="cNC1", level=10)
print(myGrid)
## 2D-Grid --> nested Gauss-Legendre rule
myGrid <- createNIGrid(dim=2, type=c("GLe","nLe"), level=c(4, 7))
rescale(myGrid, domain = rbind(c(-1,1),c(-1,1)))
plot(myGrid)
print(myGrid)
myFun <- function(x){
   1-x[,1]^2*x[,2]^2
}
quadrature(f = myFun, grid = myGrid)
## level transformation
levelTrans <- function(x){
  tmp <- as.matrix(x)
  tmp[, 2] <- 2*tmp[ ,2]
  return(tmp)
}
nw <- createNIGrid(dim=2, type="cNC1", level = 3,
   level.trans = levelTrans, ndConstruction = "sparse")
plot(nw)
```

`getNodes and getWeights` *get nodes and weights from an NIGrid-object*

Description

`getNodes` and `getWeights` extract the (potentially rescaled) nodes and weights out of an NIGrid-Object

Usage

```
getNodes(grid)

getWeights(grid)
```

Arguments

`grid`	object of class `NIGrid`

Value

Returns the nodes or weights of the given grid

See Also

`createNIGrid`

Examples

```
myGrid <- createNIGrid(dim=2, type="cNC1", level=3)
getNodes(myGrid)
getWeights(myGrid)
```

`plot (plot.NIGrid)` *plots an NIGrid-object*

Description

Plots the grid points of an NIGrid-object

Usage

```
## S3 method for class 'NIGrid'
plot(x, plot.dimension = NULL, ...)
```

Arguments

`x`	a grid of type `NIGrid`
`plot.dimension`	vector of length 1, 2 or 3. with the dimensions to be plotted (see examples)
`...`	arguments passed to the default plot command

Examples

```
myGrid <- createNIGrid(dim=4, type=c("GHe", "cNC1", "GLe", "oNC1"),
                       level=c(3,4,5,6))
plot(myGrid) ## dimension 1-min(3,dim(myGrid)) are plotted
## Free arranged plots
plot(myGrid, plot.dimension=c(4,2,1))
plot(myGrid, plot.dimension=c(1,2))
plot(myGrid, plot.dimension=c(3))
```

`print (print.NIGrid)` *prints characteristic information for an NIGrid-object*

Description

Prints characteristic information for an NIGrid-object

Usage

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

Arguments

`x`	a grid of type `NIGrid`
`...`	further arguments passed to or from other methods

Value

Prints the information for an NIGrid-object (i.a. grid size (dimensions, grid points, memory usage), type and support)

Examples

```
myGrid <- createNIGrid(dim=2, type="GHe", level=5)
print(myGrid)
```

`quadrature` *computes the approximated Integral*

Description

`quadrature` computes the integral for a given function based on an NIGrid-object

Usage

```
quadrature(f, grid = NULL, ...)
```

Arguments

`f`	a function which takes the x-values as a (n x d) matrix as a first argument
`grid`	a grid of type `NIGrid`
`...`	further arguments for the function `f`

Value

The approximated value of the integral

See Also

createNIGrid, rescale

Examples

```
myGrid <- createNIGrid(dim=2, type="GLe", level=5)
rescale(myGrid, domain=rbind(c(-1,1),c(-1,1)))
plot(myGrid, col="blue")
myFun <- function(x){
   1 - x[,1]^2 * x[,2]^2
}
quadrature(myFun, myGrid)
```

QuadRules *nodes and weights for 1D - Gauss-Quadrature*

Description

This data set stores nodes an weights for Gauss-Quadrature. Syntax:

QuadRules[['type']][['level']]

- type="**GLe**" Gauss-Legendre; interval [0,1]; max-level 45
- type="**nLe**" nested-type Gauss-Legendre; interval [0,1]; max-level 25
- type="**GKr**" Gauss-Kronrod; interval [0,1]; max-level 29
- type="**GLa**" Gauss-Laguere; interval [0, Inf); max-level 30
- type="**GHe**" Gauss-Hermite; interval (-Inf, Inf); max-level 45
- type="**GHN**" Gauss-Hermite (as above, but pre-multiplied weights $\hat(w)_i = w_i * \phi(x_i)$)
- type="**nHe**" nested-type Gauss-Hermite; interval (-Inf, Inf) max-level 25
- type="**nHN**" nested-type Gauss-Hermite (as above, but pre-multiplied weights $\hat(w)_i = w_i * \phi(x_i)$)
- type="**Leja**" Leja-points; interval [0,1]; max-level 141

Format

list of nodes and weights (for organisation see "Syntax" in description section)

Source

- http://keisan.casio.com/exec/system/1329114617 high precission computing (for G..-rules)

- further information in createNIGrid

Examples

```
nw <- QuadRules[["GHe"]][[2]]
```

---

readRule *reads a quadrature-rule from a text file*

Description

`readRule` reads a quadrature-rule from a text file

Usage

```
readRule(file = NULL)
```

Arguments

`file`	file name of the text file containing the quadrature rule

Details

The text file containing the quadrature rule has to be formatted in the following way:

The first line have to declare the domain `initial.domain a b`, where a and b denotes the lower and upper-bound for the integration domain. This can be either a number or '-Inf'/'Inf' (for example `initial.domain 0 1` or `initial.domain 0 Inf`)

Every following line contains one single node and weight belonging to one level of the rule (format: 'level' 'node' 'weight'). This example shows the use for the "midpoint-rule" (levels: 1 - 3).

> `initial.domain 0 1`

> `1 0.5 1`

> `2 0.25 0.5`

> `2 0.75 0.5`

> `3 0.166666666666667 0.333333333333333`

> `3 0.5 0.333333333333333`

> `3 0.833333333333333 0.333333333333333`

Value

Returns an object of class 'customRule', which can be used for creating a 'NIGrid' (`createNIGrid`)

See Also

`createNIGrid`

Examples

```
## Not run: myRule <- readRule(file="midpoint_rule.txt")
## Not run: nw <- createNIGrid(d=1, type = myRule.txt, level = 2)
```

`rescale (rescale.NIGrid)` *moves, rescales and/or rotates a multidimensional grid.*

Description

`rescale.NIGrid` manipulates a grid for more efficient numerical integration with respect to a given domain (bounded integral) or vector of means and covariance matrix (unbounded integral).

Usage

```
rescale(object, ...)

## S3 method for class 'NIGrid'
rescale(object, domain = NULL, m = NULL, C = NULL,
  dec.type = 0, ...)
```

Arguments

`object`	an initial grid of type `NIGrid`
`...`	further arguments passed to or from other methods
`domain`	a (d x 2)-matrix with the boundaries for each dimension
`m`	vector of means
`C`	covariance matrix
`dec.type`	type of covariance decomposition (*Peter Jaeckel (2005)*)

Value

This function modifies the "support-attribute" of the grid. The recalculation of the nodes and weights is done when the `getNodes` or `getWeights` are used.

References

Peter Jaeckel (2005): A note on multivariate Gauss-Hermite quadrature

See Also

`quadrature`, `createNIGrid`

Examples

```
C = matrix(c(2,0.9,0.9,2),2)
m = c(-.5, .3)
par(mfrow=c(3,1))

myGrid <- createNIGrid(dim=2, type="GHe", level=5)
```

```
rescale(myGrid, m=m, C=C, dec.type=0)
plot(myGrid, col="red")

rescale(myGrid, m=m, C=C, dec.type=1)
plot(myGrid, col="green")

rescale(myGrid, m=m, C=C, dec.type=2)
plot(myGrid, col="blue")
```

---

size (size.NIGrid) *returns the size of an NIGrid-object*

Description

Returns the size of an NIGrid-object

Usage

```
size(object, ...)

## S3 method for class 'NIGrid'
size(object, ...)

## S3 method for class 'NIGrid'
dim(x)
```

Arguments

`object`	a grid of type `NIGrid`
`...`	other arguments passed to the specific method
`x`	object of type `NIGrid`

Value

Returns the grid size in terms of dimensions, number of grid points and used memory

Examples

```
myGrid <- createNIGrid(dim=2, type="GHe", level=5)
size(myGrid)
dim(myGrid)
```

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