

# Package ‘NNS’

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**Type** Package

**Title** Nonlinear Nonparametric Statistics

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**Description** Nonlinear nonparametric statistics using partial moments. Partial moments are the elements of variance and asymptotically approximate the area of  $f(x)$ . These robust statistics provide the basis for nonlinear analysis while retaining linear equivalences. NNS offers: Numerical integration, Numerical differentiation, Clustering, Correlation, Dependence, Causal analysis, ANOVA, Regression, Classification, Seasonality, Autoregressive modeling, Normalization and Stochastic dominance. All routines based on: Viole, F. and Nawrocki, D. (2013), Nonlinear Nonparametric Statistics: Using Partial Moments (ISBN: 1490523995).

**License** GPL-3

**BugReports** <https://github.com/OVVO-Financial/NNS/issues>

**LazyData** TRUE

**RoxygenNote** 6.1.1

**Depends** R (>= 3.3.0), doParallel

**Imports** data.table, rgl, stringr

**Suggests** knitr, rmarkdown

**VignetteBuilder** knitr

## R topics documented:

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Co.LPM

*Co-Lower Partial Moment (Lower Left Quadrant 4)*

---

### Description

This function generates a co-lower partial moment for between two equal length variables for any degree or target.

### Usage

```
Co.LPM(degree.x, degree.y, x, y, target.x = mean(x),
       target.y = mean(y))
```

### Arguments

|          |  |
|----------|--|
| degree.x | integer; Degree for variable X. (degree.x = 0) is frequency, (degree.x = 1) is area. |
| degree.y | integer; Degree for variable Y. (degree.y = 0) is frequency, (degree.y = 1) is area. |
| x        | a numeric vector.  |
| y        | a numeric vector of equal length to x.   |

|          |  |
|----------|--|
| target.x | numeric; Typically the mean of Variable X for classical statistics equivalences, but does not have to be. (Vectorized) |
| target.y | numeric; Typically the mean of Variable Y for classical statistics equivalences, but does not have to be. (Vectorized) |

**Value**

Co-LPM of two variables

**Author(s)**

Fred Viole, OVVO Financial Systems

**References**

Viole, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments"  
<http://amzn.com/1490523995>

**Examples**

```
set.seed(123)
x <- rnorm(100) ; y <- rnorm(100)
Co.LPM(0, 0, x, y, mean(x), mean(y))
```

---

Co.UPM

---

*Co-Upper Partial Moment (Upper Right Quadrant 1)*


---

**Description**

This function generates a co-upper partial moment between two equal length variables for any degree or target.

**Usage**

```
Co.UPM(degree.x, degree.y, x, y, target.x = mean(x),
       target.y = mean(y))
```

**Arguments**

|          |  |
|----------|--|
| degree.x | integer; Degree for variable X. (degree.x = 0) is frequency, (degree.x = 1) is area.                                   |
| degree.y | integer; Degree for variable Y. (degree.y = 0) is frequency, (degree.y = 1) is area.                                   |
| x        | a numeric vector.  |
| y        | a numeric vector of equal length to x.   |
| target.x | numeric; Typically the mean of Variable X for classical statistics equivalences, but does not have to be. (Vectorized) |
| target.y | numeric; Typically the mean of Variable Y for classical statistics equivalences, but does not have to be. (Vectorized) |

**Value**

Co-UPM of two variables

**Author(s)**

Fred Viole, OVVO Financial Systems

**References**

Viole, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments"  
<http://amzn.com/1490523995>

**Examples**

```
set.seed(123)
x <- rnorm(100) ; y <- rnorm(100)
Co.UPM(0,0,x,y,mean(x),mean(y))
```

---

D.LPM

---

*Divergent-Lower Partial Moment (Lower Right Quadrant 3)*


---

**Description**

This function generates a divergent lower partial moment between two equal length variables for any degree or target.

**Usage**

```
D.LPM(degree.x, degree.y, x, y, target.x = mean(x), target.y = mean(y))
```

**Arguments**

|          |  |
|----------|--|
| degree.x | integer; Degree for variable X. (degree.x = 0) is frequency, (degree.x = 1) is area.                                   |
| degree.y | integer; Degree for variable Y. (degree.y = 0) is frequency, (degree.y = 1) is area.                                   |
| x        | a numeric vector.  |
| y        | a numeric vector of equal length to x.   |
| target.x | numeric; Typically the mean of Variable X for classical statistics equivalences, but does not have to be. (Vectorized) |
| target.y | numeric; Typically the mean of Variable Y for classical statistics equivalences, but does not have to be. (Vectorized) |

**Value**

Divergent LPM of two variables

**Author(s)**

Fred Viole, OVVO Financial Systems

## References

Viole, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments"  
<http://amzn.com/1490523995>

## Examples

```
set.seed(123)
x <- rnorm(100) ; y <- rnorm(100)
D.LPM(0, 0, x, y, mean(x), mean(y))
```

D.UPM

*Divergent-Upper Partial Moment (Upper Left Quadrant 2)*

## Description

This function generates a divergent upper partial moment between two equal length variables for any degree or target.

## Usage

```
D.UPM(degree.x, degree.y, x, y, target.x = mean(x), target.y = mean(y))
```

## Arguments

|          |  |
|----------|--|
| degree.x | integer; Degree for variable X. (degree.x = 0) is frequency, (degree.x = 1) is area.                                   |
| degree.y | integer; Degree for variable Y. (degree.y = 0) is frequency, (degree.y = 1) is area.                                   |
| x        | a numeric vector.  |
| y        | a numeric vector of equal length to x.   |
| target.x | numeric; Typically the mean of Variable X for classical statistics equivalences, but does not have to be. (Vectorized) |
| target.y | numeric; Typically the mean of Variable Y for classical statistics equivalences, but does not have to be. (Vectorized) |

## Value

Divergent UPM of two variables

## Author(s)

Fred Viole, OVVO Financial Systems

## References

Viole, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments"  
<http://amzn.com/1490523995>

## Examples

```
set.seed(123)
x <- rnorm(100) ; y <- rnorm(100)
D.UPM(0, 0, x, y, mean(x), mean(y))
```

dy.dx

*Partial Derivative dy/dx***Description**

Returns the numerical partial derivate of y wrt x for a point of interest.

**Usage**

```
dy.dx(x, y, order = NULL, stn = 0.99, eval.point = median(x),
      deriv.order = 1, h = 0.05, noise.reduction = "mean",
      deriv.method = "FS")
```

**Arguments**

|                 |  |
|-----------------|--|
| x               | a numeric vector.  |
| y               | a numeric vector.  |
| order           | integer; Controls the number of partial moment quadrant means. Defaults to (order = NULL) which generates a more accurate derivative for well specified cases.   |
| stn             | numeric [0, 1]; Signal to noise parameter, sets the threshold of <a href="#">NNS.dep</a> which reduces "order" when (order = NULL). Defaults to 0.99 to ensure high dependence for higher "order" and endpoint determination.  |
| eval.point      | numeric; x point to be evaluated. Defaults to (eval.point = median(x)). Set to (eval.point = "overall") to find an overall partial derivative estimate.  |
| deriv.order     | numeric options: (1, 2); 1 (default) for first derivative. For second derivative estimate of f(x), set (deriv.order = 2).  |
| h               | numeric [0, ...]; Percentage step used for finite step method. Defaults to h = .05 representing a 5 percent step from the value of the independent variable.   |
| noise.reduction | the method of determing regression points options: ("mean", "median", "mode", "off"); In low signal to noise situations, (noise.reduction = "median") uses medians instead of means for partitions, while (noise.reduction = "mode") uses modes instead of means for partitions. (noise.reduction = "off") allows for maximum possible fit in <a href="#">NNS.reg</a> . Default setting is (noise.reduction = "mean"). |
| deriv.method    | method of derivative estimation, options: ("NNS", "FS"); Determines the partial derivative from the coefficient of the <a href="#">NNS.reg</a> output when (deriv.method = "NNS") or generates a partial derivative using the finite step method (deriv.method = "FS") (Default).  |

**Value**

Returns the value of the partial derivative estimate for the given order.

**Note**

If a vector of derivatives is required, ensure (deriv.method = "FS").

**Author(s)**

Fred Violo, OVVO Financial Systems

**References**

Violo, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments" <http://amzn.com/1490523995>

Vinod, H. and Violo, F. (2017) "Nonparametric Regression Using Clusters" <https://link.springer.com/article/10.1007/s10614-017-9713-5>

**Examples**

```
## Not run:
x <- seq(0, 2 * pi, pi / 100) ; y <-sin(x)
dy.dx(x, y, eval.point = 1.75)

# Vector of derivatives
dy.dx(x, y, eval.point = c(1.75, 2.5), deriv.method = "FS")
## End(Not run)
```

---

dy.d\_

---

*Partial Derivative  $dy/d_{[wrt]}$* 


---

**Description**

Returns the numerical partial derivate of y with respect to [wrt] any regressor for a point of interest. Finite difference method is used with [NNS.reg](#) estimates as  $f(x + h)$  and  $f(x - h)$  values.

**Usage**

```
dy.d_(x, y, wrt, eval.points = "median", order = NULL, stn = 0.99,
      h = 0.05, n.best = NULL, mixed = FALSE, plot = FALSE,
      noise.reduction = "mean")
```

**Arguments**

|             |  |
|-------------|--|
| x           | a numeric matrix or data frame.  |
| y           | a numeric vector with compatible dimensions to x.  |
| wrt         | integer; Selects the regressor to differentiate with respect to.   |
| eval.points | numeric or options: ("mean", "median", "last"); Regressor points to be evaluated. (eval.points = "median") (default) to find partial derivatives at the median of every variable. Set to (eval.points = "last") to find partial derivatives at the last value of every variable. Set to (eval.points="mean") to find partial derivatives at the mean value of every variable. Set to (eval.points = "all") to find partial derivatives at every observation. |
| order       | integer; <a href="#">NNS.reg</a> "order", defaults to NULL.  |
| stn         | numeric [0, 1]; Signal to noise parameter, sets the threshold of <a href="#">NNS.dep</a> which reduces "order" when (order = NULL). Defaults to 0.99 to ensure high dependence for higher "order" and endpoint determination.  |

|                 |  |
|-----------------|--|
| h               | numeric [0, ...]; Percentage step used for finite step method. Defaults to h = .05 representing a 5 percent step from the value of the regressor.  |
| n.best          | integer; Sets the number of closest regression points to use in estimating finite difference points in <a href="#">NNS.reg</a> . NULL (default) Uses <code>ceiling(sqrt(ncol(x)))</code> .   |
| mixed           | logical; FALSE (default) If mixed derivative is to be evaluated, set (mixed = TRUE). Only for single valued eval.points.   |
| plot            | logical; FALSE (default) Set to (plot = TRUE) to view plot.  |
| noise.reduction | the method of determining regression points options: ("mean", "median", "mode", "off"); In low signal to noise situations, (noise.reduction = "median") uses medians instead of means for partitions, while (noise.reduction = "mode") uses modes instead of means for partitions. (noise.reduction = "off") allows for maximum possible fit in <a href="#">NNS.reg</a> . Default setting is (noise.reduction = "mean"). |

## Value

Returns:

- `dy.d(...)$"First Derivative"` the 1st derivative
- `dy.d(...)$"Second Derivative"` the 2nd derivative
- `dy.d(...)$"Mixed Derivative"` the mixed derivative (for two independent variables only).

Returns a vector of partial derivatives when (eval.points = "all").

## Note

For known function testing and analysis, regressors should be transformed via [expand.grid](#) to fill the dimensions with (order = "max"). Example provided below.

## Author(s)

Fred Viole, OVVO Financial Systems

## References

Viole, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments"  
<http://amzn.com/1490523995>

## Examples

```
## Not run:
set.seed(123) ; x_1 <- runif(100) ; x_2 <- runif(100) ; y <- x_1 ^ 2 * x_2 ^ 2
B <- cbind(x_1, x_2)
## To find derivatives of y wrt 1st regressor
dy.d_(B, y, wrt = 1, eval.points = c(.5, .5))

## Known function analysis: [y = a ^ 2 * b ^ 2]
x_1 <- seq(0, 1, .1) ; x_2 <- seq(0, 1, .1)
B <- expand.grid(x_1, x_2) ; y <- B[, 1] ^ 2 * B[, 2] ^ 2
dy.d_(B, y, wrt = 1, eval.points = c(.5, .5), order = "max")
## End(Not run)
```



---

LPM

*Lower Partial Moment*


---

**Description**

This function generates a univariate lower partial moment for any degree or target.

**Usage**

```
LPM(degree, target, variable)
```

**Arguments**

|          |   |
|----------|---|
| degree   | integer; (degree = 0) is frequency, (degree = 1) is area.             |
| target   | numeric; Typically set to mean, but does not have to be. (Vectorized) |
| variable | a numeric vector.   |

**Value**

LPM of variable

**Author(s)**

Fred Viole, OVVO Financial Systems

**References**

Viole, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments"  
<http://amzn.com/1490523995>

**Examples**

```
set.seed(123)
x <- rnorm(100)
LPM(0, mean(x), x)
```

---

LPM.ratio

*Lower Partial Moment RATIO*


---

**Description**

This function generates a standardized univariate lower partial moment for any degree or target.

**Usage**

```
LPM.ratio(degree, target, variable)
```

**Arguments**

|          |   |
|----------|---|
| degree   | integer; (degree = 0) is frequency, (degree = 1) is area.             |
| target   | numeric; Typically set to mean, but does not have to be. (Vectorized) |
| variable | a numeric vector.   |

**Value**

Standardized LPM of variable

**Author(s)**

Fred Viole, OVVO Financial Systems

**References**

Viole, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments"  
<http://amzn.com/1490523995>

**Examples**

```
set.seed(123)
x <- rnorm(100)
LPM.ratio(0, mean(x), x)

## Continuous CDF
LPM.ratio(1, sort(x), x)

## Joint CDF
## Not run:
x <- rnorm(5000) ; y <- rnorm(5000)
plot3d(x, y, Co.LPM(0, 0, sort(x), sort(y), x, y), col = "blue", xlab = "X", ylab = "Y",
zlab = "Probability", box = FALSE)

## End(Not run)
```

---

LPM.VaR

---

*LPM VaR*


---

**Description**

Generates a VaR based on the Lower Partial Moment ratio.

**Usage**

```
LPM.VaR(percentile, degree, x)
```

**Arguments**

|            |  |
|------------|--|
| percentile | numeric [0, 1]; The percentile for left-tail VaR.  |
| degree     | integer; (degree = 0) for discrete distributions, (degree = 1) for continuous distributions. |
| x          | a numeric vector.  |

**Value**

Returns a numeric value representing the point at which "percentile" of the area of x is above.

**Author(s)**

Fred Viole, OVVO Financial Systems

**References**

Viole, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments"  
<http://amzn.com/1490523995>

**Examples**

```
set.seed(123)
x <- rnorm(100)

## For 95th percentile VaR (left-tail)
LPM.VaR(0.95, 0, x)
```

---

|           |                  |
|-----------|------------------|
| NNS.ANOVA | <i>NNS ANOVA</i> |
|-----------|------------------|

---

**Description**

Analysis of variance (ANOVA) based on lower partial moment CDFs for multiple variables. Returns a degree of certainty the difference in sample means is zero, not a p-value.

**Usage**

```
NNS.ANOVA(control, treatment, confidence.interval = 0.95,
           tails = "Both", pairwise = FALSE, plot = TRUE, binary = TRUE)
```

**Arguments**

|                     |  |
|---------------------|--|
| control             | a numeric vector, matrix or data frame.  |
| treatment           | NULL (default) a numeric vector, matrix or data frame.   |
| confidence.interval | numeric [0, 1]; The confidence interval surrounding the control mean when (binary = TRUE). Defaults to (confidence.interval = 0.95).   |
| tails               | options: ("Left", "Right", "Both"). tails = "Both"(Default) Selects the tail of the distribution to determine effect size.   |
| pairwise            | logical; FALSE (default) Returns pairwise certainty tests when set to pairwise = TRUE.   |
| plot                | logical; TRUE (default) Returns the boxplot of all variables along with grand mean identification. When (binary = TRUE), returns the boxplot of both variables along with grand mean identification and confidence interval thereof. |
| binary              | logical; TRUE (default) Selects binary analysis between a control and treatment variable.  |

**Value**

For (binary = FALSE) returns the degree certainty the difference in sample means is zero [0, 1].

For (binary = TRUE) returns:

- "Control Mean"
- "Treatment Mean"
- "Grand Mean"
- "Control CDF"
- "Treatment CDF"
- "Certainty" the certainty of the same population statistic
- "Lower Bound Effect" and "Upper Bound Effect" the effect size of the treatment for the specified confidence interval

**Author(s)**

Fred Violen, OVVO Financial Systems

**References**

Violen, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments"  
<http://amzn.com/1490523995>

**Examples**

```
### Binary analysis and effect size
set.seed(123)
x <- rnorm(100) ; y <- rnorm(100)
NNS.ANOVA(control = x, treatment = y)

### Two variable analysis with no control variable
A <- cbind(x, y)
NNS.ANOVA(A)

### Multiple variable analysis with no control variable
set.seed(123)
x <- rnorm(100) ; y<- rnorm(100) ; z<- rnorm(100)
A <- cbind(x, y, z)
NNS.ANOVA(A)
```

---

NNS.ARMA

---

*NNS ARMA*


---

**Description**

Autoregressive model incorporating nonlinear regressions of component series.

**Usage**

```
NNS.ARMA(variable, h = 1, training.set = NULL,
  seasonal.factor = TRUE, weights = NULL, best.periods = 2,
  negative.values = FALSE, method = "nonlin", dynamic = FALSE,
  plot = TRUE, seasonal.plot = TRUE, intervals = FALSE,
  ncores = NULL)
```

**Arguments**

|                 |  |
|-----------------|--|
| variable        | a numeric vector.  |
| h               | integer; 1 (default) Number of periods to forecast.  |
| training.set    | numeric; NULL (default) Sets the number of variable observations (variable[1 : training.set]) to monitor performance of forecast over in-sample range.   |
| seasonal.factor | logical or integer(s); TRUE (default) Automatically selects the best seasonal lag from the seasonality test. To use weighted average of all seasonal lags set to (seasonal.factor = FALSE). Otherwise, directly input known frequency integer lag to use, i.e. (seasonal.factor = 12) for monthly data. Multiple frequency integers can also be used, i.e. (seasonal.factor = c(12, 24, 36)) |
| weights         | numeric; NULL (default) sets the weights of the seasonal.factor vector when specified as integers. If (weights = NULL) each seasonal.factor is weighted on its <a href="#">NNS.seas</a> result and number of observations it contains.   |
| best.periods    | integer; [2] (default) used in conjunction with (seasonal.factor = FALSE), uses the best.periods number of detected seasonal lags instead of ALL lags when (seasonal.factor = FALSE).  |
| negative.values | logical; FALSE (default) If the variable can be negative, set to (negative.values = TRUE).   |
| method          | options: ("lin", "nonlin", "both"); "nonlin" (default) To select the regression type of the component series, select (method = "both") where both linear and nonlinear estimates are generated. To use a nonlinear regression, set to (method = "nonlin"); to use a linear regression set to (method = "lin").   |
| dynamic         | logical; FALSE (default) To update the seasonal factor with each forecast point, set to (dynamic = TRUE). The default is (dynamic = FALSE) to retain the original seasonal factor from the inputted variable for all ensuing h.  |
| plot            | logical; TRUE (default) Returns the plot of all periods exhibiting seasonality and the variable level reference in upper panel. Lower panel returns original data and forecast.  |
| seasonal.plot   | logical; TRUE (default) Adds the seasonality plot above the forecast. Will be set to FALSE if no seasonality is detected or seasonal.factor is set to an integer value.  |
| intervals       | logical; FALSE (default) Plots the surrounding forecasts around the final estimate when (intervals = TRUE) and (seasonal.factor = FALSE). There are no other forecasts to plot when a single seasonal.factor is selected.  |
| ncores          | integer; value specifying the number of cores to be used in the parallelized procedure. If NULL (default), the number of cores to be used is equal to half the number of cores of the machine - 1.   |

**Value**

Returns a vector of forecasts of length (h).

**Note**

For monthly data series, increased accuracy may be realized from forcing seasonal factors to multiples of 12. For example, if the best periods reported are: {37, 47, 71, 73} use (seasonal.factor = c(36, 48, 72)).

(seasonal.factor = FALSE) can be a very computationally expensive exercise due to the number of seasonal periods detected.

If error encountered when (seasonal.factor = TRUE):

"NaNs produced Error in seq.default(length(variable)+1, 1, -lag[i]) : wrong sign in 'by' argument"

use the combination of (seasonal.factor = FALSE, best.periods = 1).

### Author(s)

Fred Viole, OVVO Financial Systems

### References

Viole, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments"  
<http://amzn.com/1490523995>

### Examples

```
## Nonlinear NNS.ARMA using AirPassengers monthly data and 12 period lag
## Not run:
NNS.ARMA(AirPassengers, h = 45, training.set = 100, seasonal.factor = 12, method = "nonlin")

## Linear NNS.ARMA using AirPassengers monthly data and 12, 24, and 36 period lags
NNS.ARMA(AirPassengers, h = 45, training.set = 120, seasonal.factor = c(12, 24, 36), method = "lin")

## Nonlinear NNS.ARMA using AirPassengers monthly data and 2 best periods lag
NNS.ARMA(AirPassengers, h = 45, training.set = 120, seasonal.factor = FALSE, best.periods = 2)
## End(Not run)
```

---

NNS.ARMA.optim

*NNS ARMA Optimizer*

---

### Description

Wrapper function for optimizing any combination of a given seasonal.factor vector in [NNS.ARMA](#). Minimum sum of squared errors (forecast-actual) is used to determine optimum across all [NNS.ARMA](#) methods.

### Usage

```
NNS.ARMA.optim(variable, training.set, seasonal.factor,
  negative.values = FALSE, obj.fn = expression(sum((predicted -
  actual)^2)), objective = "min", linear.approximation = TRUE,
  depth = 1, print.trace = TRUE, ncores = NULL, subcores = NULL)
```

**Arguments**

|                                   |  |
|-----------------------------------|--|
| <code>variable</code>             | a numeric vector.  |
| <code>training.set</code>         | numeric; NULL (default) Sets the number of variable observations   |
| <code>seasonal.factor</code>      | integers; Multiple frequency integers considered for <a href="#">NNS.ARMA</a> model, i.e. ( <code>seasonal.factor = c(12, 24, 36)</code> )   |
| <code>negative.values</code>      | logical; FALSE (default) If the variable can be negative, set to ( <code>negative.values = TRUE</code> ).  |
| <code>obj.fn</code>               | expression; <code>expression(sum((predicted - actual)^2))</code> (default) Sum of squared errors is the default objective function. Any <code>expression()</code> using the specific terms <code>predicted</code> and <code>actual</code> can be used. |
| <code>objective</code>            | options: ("min", "max") "min" (default) Select whether to minimize or maximize the objective function <code>obj.fn</code> .  |
| <code>linear.approximation</code> | logical; TRUE (default) Uses the best linear output from <code>NNS.reg</code> to generate a nonlinear and mixture regression for comparison. FALSE is a more exhaustive search over the objective space.   |
| <code>depth</code>                | integer; <code>depth = 1</code> (default) Sets the level from which further combinations are generated containing only members from prior level's best <code>seasonal.factors</code> .   |
| <code>print.trace</code>          | logical; TRUE (default) Prints current iteration information. Suggested as backup in case of error, best parameters to that point still known and copyable!  |
| <code>ncores</code>               | integer; value specifying the number of cores to be used in the parallelized procedure. If NULL (default), the number of cores to be used is equal to half the number of cores of the machine.   |
| <code>subcores</code>             | integer; value specifying the number of cores to be used in the parallelized procedure in the subroutine <a href="#">NNS.ARMA</a> . If NULL (default), the number of cores to be used is equal to half the number of cores of the machine - 1.         |

**Value**

Returns a list containing:

- `$period` a vector of optimal seasonal periods
- `$weights` the optimal weights of each seasonal period between an equal weight or NULL weighting
- `$obj.fn` the minimum objective function value
- `$method` the method identifying which [NNS.ARMA](#) method was used.

**Note**

The number of combinations will grow prohibitively large, they should be kept to a minimum when (`method = "comb"`).

`seasonal.factor` containing an element too large will result in an error. Please reduce the maximum `seasonal.factor`.

**Author(s)**

Fred Viole, OVVO Financial Systems

## References

Viole, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments"  
<http://amzn.com/1490523995>

## Examples

```
## Nonlinear NNS.ARMA period optimization using 2 yearly lags on AirPassengers monthly data
## Not run:
nns.optims <- NNS.ARMA.optim(AirPassengers[1:132], training.set = 120,
seasonal.factor = seq(12, 24, 6))

## Then use optimal parameters in NNS.ARMA to predict 12 periods in-sample
NNS.ARMA(AirPassengers, h=12, training.set=132,
seasonal.factor = nns.optims$periods, method = nns.optims$method)

## End(Not run)
```

---

NNS.boost

*NNS Boost*


---

## Description

Ensemble method for classification using the predictions of the NNS multivariate regression [NNS.reg](#) collected from uncorrelated feature combinations.

## Usage

```
NNS.boost(IVs.train, DV.train, IVs.test, representative.sample = TRUE,
depth = NULL, n.best = 3, learner.trials = NULL, epochs = NULL,
CV.size = 0.25, threshold = NULL,
obj.fn = expression(mean(round(predicted) == as.numeric(actual))),
objective = "max", extreme = FALSE, feature.importance = TRUE,
status = TRUE, ncores = NULL, subcores = NULL)
```

## Arguments

|                       |   |
|-----------------------|---|
| IVs.train             | a matrix or data frame of variables of numeric or factor data types.  |
| DV.train              | a numeric or factor vector with compatible dimensions to (IVs.train).   |
| IVs.test              | a matrix or data frame of variables of numeric or factor data types with compatible dimensions to (IVs.train).  |
| representative.sample | logical; TRUE (default) Reduces observations of IVs.train to a set of representative observations per regressor.  |
| depth                 | integer; NULL (default) Specifies the order parameter in the NNS.reg routine, assigning a number of splits in the regressors. (depth = "max") will be significantly faster, but increase the variance of results. |
| n.best                | integer; 3 (default) Sets the number of nearest regression points to use in weighting for multivariate regression at sqrt(# of regressors). Analogous to k in a k Nearest Neighbors algorithm.                    |



|                                 |   |
|---------------------------------|---|
| <code>learner.trials</code>     | integer; NULL (default) Sets the number of trials to obtain an accuracy threshold level. Number of observations in the training set is the default setting.   |
| <code>epochs</code>             | integer; $2 \times \text{length}(\text{DV.train})$ (default) Total number of feature combinations to run.   |
| <code>CV.size</code>            | numeric [0, 1]; ( <code>CV.size = .25</code> ) (default) Sets the cross-validation size. Defaults to 0.25 for a 25 percent random sampling of the training set.   |
| <code>threshold</code>          | numeric [0, 1]; NULL (default) Sets the <code>obj.fn</code> accuracy threshold to keep feature combinations.  |
| <code>obj.fn</code>             | expression; <code>expression(mean(round(predicted)==as.numeric(actual)))</code> (default) Mean accuracy is the default objective function. Any <code>expression()</code> using the specific terms <code>predicted</code> and <code>actual</code> can be used. |
| <code>objective</code>          | options: ("min", "max") "max" (default) Select whether to minimize or maximize the objective function <code>obj.fn</code> .   |
| <code>extreme</code>            | logical; FALSE (default) Uses the maximum (minimum) threshold obtained from the <code>learner.trials</code> , rather than the upper (lower) quintile level for maximization (minimization) objective.   |
| <code>feature.importance</code> | logical; TRUE (default) Plots the frequency of features used in the final estimate.   |
| <code>status</code>             | logical; TRUE (default) Prints status update message in console.  |
| <code>ncores</code>             | integer; value specifying the number of cores to be used in the parallelized procedure. If NULL (default), the number of cores to be used is equal to half the number of cores of the machine.  |
| <code>subcores</code>           | integer; value specifying the number of cores to be used in the parallelized procedure in the subroutine <a href="#">NNS.reg</a> . If NULL (default), the number of cores to be used is equal to half the number of cores of the machine - 1.                 |

**Value**

Returns a vector of fitted values for the dependent variable test set `$results`, and the final feature loadings `$feature.weights`.

**Author(s)**

Fred Violen, OVVO Financial Systems

**References**

Violen, F. (2016) "Classification Using NNS Clustering Analysis" <https://ssrn.com/abstract=2864711>

**Examples**

```
## Using 'iris' dataset where test set [IVs.test] is 'iris' rows 141:150.
## Not run:
a <- NNS.boost(iris[1:140, 1:4], iris[1:140, 5],
IVs.test = iris[141:150, 1:4],
epochs = 100, learner.trials = 100)

## Test accuracy
mean(round(a$results)==as.numeric(iris[141:150,5]))

## End(Not run)
```

NNS.caus

*NNS Causation***Description**

Returns the causality from observational data between two variables.

**Usage**

```
NNS.caus(x, y, factor.2.dummy = TRUE, tau, time.series = FALSE,
         plot = FALSE)
```

**Arguments**

|                             |   |
|-----------------------------|---|
| <code>x</code>              | a numeric vector, matrix or data frame.   |
| <code>y</code>              | NULL (default) or a numeric vector with compatible dimensions to <code>x</code> .   |
| <code>factor.2.dummy</code> | logical; TRUE (default) Automatically augments variable matrix with numerical dummy variables based on the levels of factors. Includes dependent variable <code>y</code> .  |
| <code>tau</code>            | options: ("cs", "ts", integer); Number of lagged observations to consider (for time series data). Otherwise, set ( <code>tau = "cs"</code> ) for cross-sectional data. ( <code>tau = "ts"</code> ) automatically selects the lag of the time series data, while ( <code>tau = [integer]</code> ) specifies a time series lag. |
| <code>time.series</code>    | logical; FALSE (default) If analyzing time series data with <code>tau = [integer]</code> , select ( <code>time.series = TRUE</code> ). Not required when ( <code>tau = "ts"</code> ).   |
| <code>plot</code>           | logical; FALSE (default) Plots the raw variables, tau normalized, and cross-normalized variables.   |

**Value**

Returns the directional causation ( $x \longrightarrow y$ ) or ( $y \longrightarrow x$ ) and net quantity of association. For causal matrix, directional causation is returned as ([column variable]  $\longrightarrow$  [row variable]). Negative numbers represent causal direction attributed to [row variable].

**Author(s)**

Fred Viole, OVVO Financial Systems

**References**

Viole, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments"  
<http://amzn.com/1490523995>

**Examples**

```
## x clearly causes y...
## Not run:
set.seed(123)
x <- rnorm(100) ; y <- x ^ 2
NNS.caus(x, y, tau = "cs")

x <- 1:100 ; y <- x^2
```

```

NNS.caus(x, y, tau = "ts", time.series = TRUE)

## Causal matrix
NNS.caus(data.matrix(iris), tau = 0)

## End(Not run)

```

---

NNS.cor

*NNS Correlation*


---

## Description

Returns the nonlinear correlation between two variables based on higher order partial moment matrices measured by frequency or area.

## Usage

```
NNS.cor(x, y = NULL, order = NULL, degree = NULL)
```

## Arguments

|        |  |
|--------|--|
| x      | a numeric vector, matrix or data frame.  |
| y      | NULL (default) or a numeric vector with compatible dimensions to x.  |
| order  | integer; Controls the level of quadrant partitioning. Defaults to (order = NULL). Errors can generally be rectified by setting (order = 1).                            |
| degree | integer; (degree = 0) is frequency based correlations, while (degree = 1) is for area based correlations. Defaults to (degree = 0) for smaller number of observations. |

## Value

Returns nonlinear correlation coefficient between two variables, or nonlinear correlation matrix for matrix input.

## Note

p-values and confidence intervals can be obtained from sampling random permutations of  $y_p$  and running `NNS.dep(x, y_p)` to compare against a null hypothesis of 0 correlation or dependence between  $x, y$ .

## Author(s)

Fred Viole, OVVO Financial Systems

## References

Viole, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments"  
<http://amzn.com/1490523995>

**Examples**

```

set.seed(123)
## Pairwise Correlation
x <- rnorm(100) ; y <- rnorm(100)
NNS.cor(x, y)

## Correlation Matrix
x <- rnorm(100) ; y <- rnorm(100) ; z<-rnorm(100)
B <- cbind(x, y, z)
NNS.cor(B)

```

NNS.cor.hd

*NNS Co-Partial Moments Higher Dimension Correlation***Description**

Determines higher dimension correlation coefficients based on degree 0 co-partial moments.

**Usage**

```
NNS.cor.hd(x, plot = FALSE, independence.overlay = FALSE)
```

**Arguments**

|                      |   |
|----------------------|---|
| x                    | a numeric matrix or data frame.   |
| plot                 | logical; FALSE (default) Generates a 3d scatter plot with regression points using <a href="#">plot3d</a> .  |
| independence.overlay | logical; FALSE (default) Creates and overlays independent <a href="#">Co.LPM</a> and <a href="#">Co.UPM</a> regions to visually reference the difference in dependence from the data.frame of variables being analyzed. Under independence, the light green and red shaded areas would be occupied by green and red data points respectively. |

**Value**

Returns multivariate nonlinear correlation coefficient

**Author(s)**

Fred Viole, OVVO Financial Systems

**References**

Viole, F. (2016) "Beyond Correlation: Using the Elements of Variance for Conditional Means and Probabilities" <http://ssrn.com/abstract=2745308>.

**Examples**

```

set.seed(123)
x <- rnorm(1000) ; y <- rnorm(1000) ; z <- rnorm(1000)
A <- data.frame(x, y, z)
NNS.cor.hd(A, plot = TRUE, independence.overlay = TRUE)

```

NNS.dep

*NNS Dependence***Description**

Returns the dependence and nonlinear correlation between two variables based on higher order partial moment matrices measured by frequency or area.

**Usage**

```
NNS.dep(x, y = NULL, order = NULL, degree = NULL,
        print.map = FALSE, ncores = NULL)
```

**Arguments**

|           |   |
|-----------|---|
| x         | a numeric vector, matrix or data frame.   |
| y         | NULL (default) or a numeric vector with compatible dimensions to x.   |
| order     | integer; Controls the level of quadrant partitioning. Defaults to (order = NULL). Errors can generally be rectified by setting (order = 1). Will not partition further if less than 4 observations exist in a quadrant. |
| degree    | integer; Defaults to NULL to allow number of observations to be "degree" determinant.   |
| print.map | logical; FALSE (default) Plots quadrant means.  |
| ncores    | integer; value specifying the number of cores to be used in the parallelized procedure. If NULL (default), the number of cores to be used is equal to the number of cores of the machine - 1.                           |

**Value**

Returns the bi-variate "Correlation" and "Dependence" or correlation / dependence matrix for matrix input.

**Note**

p-values and confidence intervals can be obtained from sampling random permutations of y\_p and running NNS.dep(x, y\_p) to compare against a null hypothesis of 0 correlation or dependence between x, y.

**Author(s)**

Fred Viole, OVVO Financial Systems

**References**

Viole, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments" <http://amzn.com/1490523995>

**Examples**

```

set.seed(123)
x <- rnorm(100) ; y <- rnorm(100)
NNS.dep(x, y)

## Correlation / Dependence Matrix
x <- rnorm(100) ; y <- rnorm(100) ; z <- rnorm(100)
B <- cbind(x, y, z)
NNS.dep(B)

## Not run:
## p-values for \code{NNS.dep}
x=seq(-5,5,.1);y=x^2+rnorm(length(x))

nns_cor_dep = NNS.dep(x,y,print.map = TRUE)
nns_cor_dep

## Create permutations of y
y_p = replicate(1000,sample.int(length(y)))

## Generate new correlation and dependence measures on each new permutation of y
nns.mc = apply(y_p,2,function(g) NNS.dep(x,y[g]))

## Store results
cors = unlist(lapply(nns.mc, "[",1))
deps = unlist(lapply(nns.mc, "[",2))

## View results
hist(cors)
hist(deps)

## Left tailed correlation p-value
cor_p_value = LPM(0,nns_cor_dep$Correlation,cors)
cor_p_value

## Right tailed correlation p-value
cor_p_value = UPM(0,nns_cor_dep$Correlation,cors)
cor_p_value

## Two sided correlation p-value
cor_p_value = UPM(0,abs(nns_cor_dep$Correlation),abs(cors))
cor_p_value

## Left tailed dependence p-value
dep_p_value = LPM(0,nns_cor_dep$Dependence,deps)
dep_p_value

## Right tailed dependence p-value
dep_p_value = UPM(0,nns_cor_dep$Dependence,deps)
dep_p_value

## Confidence Intervals
## For 95th percentile VaR (both-tails) see \link{LPM.VaR} and \link{UPM.VaR}
## Lower CI
LPM.VaR(.975,0,cors)

```

```
## Upper CI
UPM.VaR(.975,0,cors)

## End(Not run)
```

---

|              |                            |
|--------------|----------------------------|
| NNS.dep.base | <i>NNS Dependence Base</i> |
|--------------|----------------------------|

---

### Description

Internal function for NNS dependence [NNS.dep](#) parallel instances.

### Usage

```
NNS.dep.base(x, y = NULL, order = NULL, degree = NULL,
  print.map = FALSE)
```

### Arguments

|           |                               |
|-----------|-------------------------------|
| x         | from <a href="#">NNS.part</a> |
| y         | from <a href="#">NNS.part</a> |
| order     | from <a href="#">NNS.part</a> |
| degree    | from <a href="#">NNS.part</a> |
| print.map | from <a href="#">NNS.part</a> |

### Value

Returns NNS dependence.

---

|          |                                      |
|----------|--------------------------------------|
| NNS.diff | <i>NNS Numerical Differentiation</i> |
|----------|--------------------------------------|

---

### Description

Determines numerical derivative of a given function using projected secant lines on the y-axis. These projected points infer finite steps h, in the finite step method.

### Usage

```
NNS.diff(f, point, h = 0.1, tol = 1e-10, print.trace = FALSE)
```

### Arguments

|             |  |
|-------------|--|
| f           | an expression or call or a formula with no lhs.  |
| point       | numeric; Point to be evaluated for derivative of a given function f.                                   |
| h           | numeric [0, ...]; Initial step for secant projection. Defaults to (h = 0.1).                           |
| tol         | numeric; Sets the tolerance for the stopping condition of the inferred h. Defaults to (tol = 1e-10).   |
| print.trace | logical; FALSE (default) Displays each iteration, lower y-intercept, upper y-intercept and inferred h. |

**Value**

Returns a matrix of values, intercepts, derivatives, inferred step sizes for multiple methods of estimation.

**Author(s)**

Fred Viole, OVVO Financial Systems

**References**

Viole, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments"  
<http://amzn.com/1490523995>

**Examples**

```
f <- function(x) sin(x) / x
NNS.diff(f, 4.1)
```

---

|              |                     |
|--------------|---------------------|
| NNS.distance | <i>NNS Distance</i> |
|--------------|---------------------|

---

**Description**

Internal function for NNS multivariate regression [NNS.reg](#) parallel instances.

**Usage**

```
NNS.distance(rpm, dist.estimate, type, k)
```

**Arguments**

|               |  |
|---------------|--|
| rpm           | REGRESSION.POINT.MATRIX from <a href="#">NNS.reg</a> |
| dist.estimate | Vector to generate distances from.                   |
| type          | "L1" or "L2"   |
| k             | n.best from <a href="#">NNS.reg</a>                  |

**Value**

Returns sum of weighted distances.



---

|         |                     |
|---------|---------------------|
| NNS.FSD | <i>NNS FSD Test</i> |
|---------|---------------------|

---

## Description

Bi-directional test of first degree stochastic dominance using lower partial moments.

## Usage

```
NNS.FSD(x, y, type = "discrete")
```

## Arguments

|      |  |
|------|--|
| x    | a numeric vector.  |
| y    | a numeric vector.  |
| type | options: ("discrete", "continuous"); "discrete" (default) selects the type of CDF. |

## Value

Returns one of the following FSD results: "X FSD Y", "Y FSD X", or "NO FSD EXISTS".

## Author(s)

Fred Viole, OVVO Financial Systems

## References

Viole, F. and Nawrocki, D. (2016) "LPM Density Functions for the Computation of the SD Efficient Set." Journal of Mathematical Finance, 6, 105-126. <http://www.scirp.org/Journal/PaperInformation.aspx?PaperID=63817>.

Viole, F. (2017) "A Note on Stochastic Dominance." <https://ssrn.com/abstract=3002675>.

## Examples

```
set.seed(123)
x <- rnorm(100) ; y <- rnorm(100)
NNS.FSD(x, y)
```

---

NNS.FSD.uni

*NNS FSD Test uni-directional*


---

### Description

Uni-directional test of first degree stochastic dominance using lower partial moments used in SD Efficient Set routine.

### Usage

```
NNS.FSD.uni(x, y, type = "discrete")
```

### Arguments

|      |  |
|------|--|
| x    | a numeric vector.  |
| y    | a numeric vector.  |
| type | options: ("discrete", "continuous"); "discrete" (default) selects the type of CDF. |

### Value

Returns (1) if "X FSD Y", else (0).

### Author(s)

Fred Viole, OVVO Financial Systems

### References

Viole, F. and Nawrocki, D. (2016) "LPM Density Functions for the Computation of the SD Efficient Set." Journal of Mathematical Finance, 6, 105-126. <http://www.scirp.org/Journal/PaperInformation.aspx?PaperID=63817>.

Viole, F. (2017) "A Note on Stochastic Dominance." <https://ssrn.com/abstract=3002675>.

### Examples

```
set.seed(123)
x <- rnorm(100) ; y <- rnorm(100)
NNS.FSD.uni(x, y)
```

---

NNS.normNNS Normalization

---

## Description

Normalizes a matrix of variables based on nonlinear scaling normalization method.

## Usage

```
NNS.norm(A, linear = FALSE, chart.type = NULL, location = "topleft")
```

## Arguments

|            |   |
|------------|---|
| A          | a numeric matrix or data frame.   |
| linear     | logical; FALSE (default) Performs a linear scaling normalization, resulting in equal means for all variables.         |
| chart.type | options: ("l", "b"); NULL (default). Set (chart.type = "l") for line, (chart.type = "b") for boxplot.                 |
| location   | Sets the legend location within the plot, per the x and y co-ordinates used in base graphics <a href="#">legend</a> . |

## Value

Returns a [data.frame](#) of normalized values.

## Author(s)

Fred Viole, OVVO Financial Systems

## References

Viole, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments"  
<http://amzn.com/1490523995>

## Examples

```
set.seed(123)
x <- rnorm(100) ; y<-rnorm(100)
A <- cbind(x, y)
NNS.norm(A)
```

NNS.part

*NNS Partition Map***Description**

Creates partitions based on partial moment quadrant means, iteratively assigning identifications to observations based on those quadrants (unsupervised partitional and hierarchial clustering method). Basis for correlation [NNS.cor](#), dependence [NNS.dep](#), regression [NNS.reg](#) routines.

**Usage**

```
NNS.part(x, y, Voronoi = FALSE, type = NULL, order = NULL,
        obs.req = 8, min.obs.stop = FALSE, noise.reduction = "mean")
```

**Arguments**

|                 |  |
|-----------------|--|
| x               | a numeric vector.  |
| y               | a numeric vector with compatible dimensions to x.  |
| Voronoi         | logical; FALSE (default) Displays a Voronoi type diagram using partial moment quadrants.   |
| type            | NULL (default) Controls the partitioning basis. Set to (type = "XONLY") for X-axis based partitioning. Defaults to NULL for both X and Y-axis partitioning.  |
| order           | integer; Number of partial moment quadrants to be generated. (order = "max") will institute a perfect fit.   |
| obs.req         | integer; (8 default) Required observations per cluster where quadrants will not be further partitioned if observations are not greater than the entered value. Reduces minimum number of necessary observations in a quadrant to 1 when (obs.req = 1).   |
| min.obs.stop    | logical; FALSE (default) Stopping condition where quadrants will not be further partitioned if a single cluster contains less than the entered value of obs.req.   |
| noise.reduction | the method of determing regression points options: ("mean", "median", "mode", "off"); (noise.reduction = "median") uses medians instead of means for partitions, while (noise.reduction = "mode") uses modes instead of means for partitions. Defaults to (noise.reduction = "mean"), while (noise.reduction = "off") will partition quadrant to a single observation for a given (order = ...). |

**Value**

Returns:

- "dt" a [data.table](#) of x and y observations with their partition assignment "quadrant" in the 3rd column and their prior partition assignment "prior.quadrant" in the 4th column.
- "regression.points" the [data.table](#) of regression points for that given (order = ...).
- "order" the order of the final partition given "min.obs.stop" stopping condition.

**Author(s)**

Fred Viole, OVVO Financial Systems

## References

Violo, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments"  
<http://amzn.com/1490523995>

## Examples

```
set.seed(123)
x <- rnorm(100) ; y <- rnorm(100)
NNS.part(x, y)

## Data.table of observations and partitions
NNS.part(x, y, order = 1)$dt

## Regression points
NNS.part(x, y, order = 1)$regression.points

## Voronoi style plot
NNS.part(x, y, Voronoi = TRUE)

## Examine final counts by quadrant
DT <- NNS.part(x, y)$dt
DT[, counts := .N, by = quadrant]
DT
```

---

NNS.PDF

*NNS PDF*


---

## Description

This function generates an empirical PDF using continuous CDFs from [LPM.ratio](#).

## Usage

```
NNS.PDF(variable, degree = 1, target = NULL, bins = NULL,
        plot = TRUE)
```

## Arguments

|          |   |
|----------|---|
| variable | a numeric vector.   |
| degree   | integer; (degree = 0) is frequency, (degree = 1) (default) is area.                         |
| target   | a numeric range of values [a,b] where a < b. NULL (default) uses the variable observations. |
| bins     | numeric; NULL (default) Selects number of observations as default bins.                     |
| plot     | logical; plots PDF.   |

## Value

Returns a data.table containing the intervals used and resulting PDF of the variable.

## Author(s)

Fred Violo, OVVO Financial Systems

## References

Viole, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments"  
<http://amzn.com/1490523995>

## Examples

```
set.seed(123)
x <- rnorm(100)
NNS.PDF(x)

## Custom target range
NNS.PDF(x, target = c(-5, 5))
```

---

NNS.reg

*NNS Regression*


---

## Description

Generates a nonlinear regression based on partial moment quadrant means.

## Usage

```
NNS.reg(x, y, factor.2.dummy = TRUE, order = NULL, stn = 0.95,
  dim.red.method = NULL, tau = NULL, type = NULL, point.est = NULL,
  location = "top", return.values = TRUE, plot = TRUE,
  plot.regions = FALSE, residual.plot = TRUE, std.errors = FALSE,
  confidence.interval = NULL, threshold = 0, n.best = NULL,
  noise.reduction = "mean", norm = NULL, dist = "L2",
  ncores = NULL, multivariate.call = FALSE)
```

## Arguments

|                |  |
|----------------|--|
| x              | a vector, matrix or data frame of variables of numeric or factor data types.   |
| y              | a numeric or factor vector with compatible dimensions to x.  |
| factor.2.dummy | logical; TRUE (default) Automatically augments variable matrix with numerical dummy variables based on the levels of factors.  |
| order          | integer; Controls the number of partial moment quadrant means. Users are encouraged to try different (order = ...) integer settings with (noise.reduction = "off"). (order = "max") will force a limit condition perfect fit.  |
| stn            | numeric [0, 1]; Signal to noise parameter, sets the threshold of (NNS.dep) which reduces ("order") when (order = NULL). Defaults to 0.95 to ensure high dependence for higher ("order") and endpoint determination.  |
| dim.red.method | options: ("cor", "NNS.dep", "NNS.caus", "all", NULL) method for determining synthetic X* coefficients. Selection of a method automatically engages the dimension reduction regression. The default is NULL for full multivariate regression. (dim.red.method = "NNS.dep") uses <a href="#">NNS.dep</a> for nonlinear dependence weights, while (dim.red.method = "NNS.caus") uses <a href="#">NNS.caus</a> for causal weights. (dim.red.method = "cor") uses standard linear correlation for weights. (dim.red.method = "all") averages all methods for further feature engineering. |

|                     |   |
|---------------------|---|
| tau                 | options("ts", NULL); NULL (default) To be used in conjunction with (dim.red.method = "NNS.caus") or (dim.red.method = "all"). If the regression is using time-series data, set (tau = "ts") for more accurate causal analysis.  |
| type                | NULL (default). To perform a classification, set to (type = "CLASS").   |
| point.est           | a numeric or factor vector with compatible dimensions to x. Returns the fitted value y.hat for any value of x.  |
| location            | Sets the legend location within the plot, per the x and y co-ordinates used in base graphics <a href="#">legend</a> .   |
| return.values       | logical; TRUE (default), set to FALSE in order to only display a regression plot and call values as needed.   |
| plot                | logical; TRUE (default) To plot regression.   |
| plot.regions        | logical; FALSE (default). Generates 3d regions associated with each regression point for multivariate regressions. Note, adds significant time to routine.  |
| residual.plot       | logical; TRUE (default) To plot y.hat and Y.  |
| std.errors          | logical; FALSE (default) To provide standard errors of each linear segment in the "Fitted.xy" output.   |
| confidence.interval | numeric [0, 1]; NULL (default) Plots the associated confidence interval with the estimate and reports the standard error for each individual segment.   |
| threshold           | numeric [0, 1]; (threshold = 0) (default) Sets the threshold for dimension reduction of independent variables when (dim.red.method) is not NULL.  |
| n.best              | integer; NULL (default) Sets the number of nearest regression points to use in weighting for multivariate regression at sqrt(# of regressors). (n.best = "all") will select and weight all generated regression points. Analogous to k in a k Nearest Neighbors algorithm. Different values of n.best are tested using cross-validation in <a href="#">NNS.stack</a> .  |
| noise.reduction     | the method of determining regression points options: ("mean", "median", "mode", "off"); In low signal:noise situations, (noise.reduction = "mean") uses means for <a href="#">NNS.dep</a> restricted partitions, (noise.reduction = "median") uses medians instead of means for <a href="#">NNS.dep</a> restricted partitions, while (noise.reduction = "mode") uses modes instead of means for <a href="#">NNS.dep</a> restricted partitions. (noise.reduction = "off") allows for maximum possible fit with a specific order. |
| norm                | NULL (default) the method of normalization options: ("NNS", "std"); Normalizes x between 0 and 1 for multivariate regression when set to (norm = "std"), or normalizes x according to <a href="#">NNS.norm</a> when set to (norm = "NNS").  |
| dist                | options:("L1", "L2") the method of distance calculation; Selects the distance calculation used. dist = "L2" (default) selects the Euclidean distance and (dist = "L1") selects the Manhattan distance.  |
| ncores              | integer; value specifying the number of cores to be used in the parallelized procedure. If NULL (default), the number of cores to be used is equal to the number of cores of the machine - 1.   |
| multivariate.call   | Internal parameter for multivariate regressions.  |

## Value

UNIVARIATE REGRESSION RETURNS THE FOLLOWING VALUES:

- "R2" provides the goodness of fit;
- "SE" returns the overall standard error of the estimate between  $y$  and  $\hat{y}$ ;
- "Prediction.Accuracy" returns the correct rounded "Point.est" used in classifications versus the categorical  $y$ ;
- "derivative" for the coefficient of the  $x$  and its applicable range;
- "Point" returns the  $x$  point(s) being evaluated;
- "Point.est" for the predicted value generated;
- "regression.points" provides the points used in the regression equation for the given order of partitions;
- "Fitted" returns a vector containing only the fitted values,  $\hat{y}$ ;
- "Fitted.xy" returns a [data.table](#) of  $x, y, \hat{y}$ , and NNS.ID;

#### MULTIVARIATE REGRESSION RETURNS THE FOLLOWING VALUES:

- "R2" provides the goodness of fit;
- "equation" returns the numerator of the synthetic  $X^*$  dimension reduction equation as a [data.table](#) consisting of regressor and its coefficient. Denominator is simply the length of all coefficients  $> 0$ , returned in last row of equation [data.table](#).
- " $x.star$ " returns the synthetic  $X^*$  as a vector;
- "rhs.partitions" returns the partition points for each regressor  $x$ ;
- "RPM" provides the Regression Point Matrix, the points for each  $x$  used in the regression equation for the given order of partitions;
- "Point.est" returns the predicted value generated;
- "Fitted" returns a vector containing only the fitted values,  $\hat{y}$ ;
- "Fitted.xy" returns a [data.table](#) of  $x, y, \hat{y}$ , gradient, and NNS.ID.

#### Note

Please ensure `point.est` is of compatible dimensions to  $x$ , error message will ensue if not compatible.

#### Author(s)

Fred Violo, OVVO Financial Systems

#### References

Violo, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments" <http://amzn.com/1490523995>

Vinod, H. and Violo, F. (2017) "Nonparametric Regression Using Clusters" <https://link.springer.com/article/10.1007/s10614-017-9713-5>

#### Examples

```
## Not run:
set.seed(123)
x <- rnorm(100) ; y <- rnorm(100)
NNS.reg(x, y)

## Manual {order} selection
```



```

NNS.reg(x, y, order = 2)

## Maximum {order} selection
NNS.reg(x, y, order = "max")

## x-only partitioning (Univariate only)
NNS.reg(x, y, type = "XONLY")

## For Multiple Regression:
x <- cbind(rnorm(100), rnorm(100), rnorm(100)) ; y <- rnorm(100)
NNS.reg(x, y, point.est = c(.25, .5, .75))

## For Multiple Regression based on Synthetic X* (Dimension Reduction):
x <- cbind(rnorm(100), rnorm(100), rnorm(100)) ; y<-rnorm(100)
NNS.reg(x, y, point.est = c(.25, .5, .75), dim.red.method = "cor")

## IRIS dataset examples:
# Dimension Reduction:
NNS.reg(iris[,1:4], iris[,5], dim.red.method = "cor", order = 5)

# Dimension Reduction using causal weights:
NNS.reg(iris[,1:4], iris[,5], dim.red.method = "NNS.caus", order = 5)

# Multiple Regression:
NNS.reg(iris[,1:4], iris[,5], order = 2, noise.reduction = "off")

# Classification:
NNS.reg(iris[,1:4], iris[,5], point.est = iris[1:10, 1:4], type = "CLASS")$Point.est

## To call fitted values:
x <- rnorm(100) ; y <- rnorm(100)
NNS.reg(x, y)$Fitted

## To call partial derivative (univariate regression only):
NNS.reg(x, y)$derivative
## End(Not run)

```

---

NNS.SD.efficient.set    *NNS SD Efficient Set*

---

## Description

Determines the set of stochastic dominant variables for various degrees.

## Usage

```
NNS.SD.efficient.set(x, degree, type = "discrete")
```

## Arguments

|        |  |
|--------|--|
| x      | a numeric matrix or data frame.  |
| degree | numeric options: (1, 2, 3); Degree of stochastic dominance test from (1, 2 or 3).  |
| type   | options: ("discrete", "continuous"); "discrete" (default) selects the type of CDF. |

**Value**

Returns set of stochastic dominant variable names.

**Author(s)**

Fred Viole, OVVO Financial Systems

**References**

Viole, F. and Nawrocki, D. (2016) "LPM Density Functions for the Computation of the SD Efficient Set." Journal of Mathematical Finance, 6, 105-126. <http://www.scirp.org/Journal/PaperInformation.aspx?PaperID=63817>.

Viole, F. (2017) "A Note on Stochastic Dominance." <https://ssrn.com/abstract=3002675>.

**Examples**

```
set.seed(123)
x <- rnorm(100) ; y<-rnorm(100) ; z<-rnorm(100)
A <- cbind(x, y, z)
NNS.SD.efficient.set(A, 1)
```

---

|          |                             |
|----------|-----------------------------|
| NNS.seas | <i>NNS Seasonality Test</i> |
|----------|-----------------------------|

---

**Description**

Seasonality test based on the coefficient of variance for the variable and lagged component series.  
A result of 1 signifies no seasonality present.

**Usage**

```
NNS.seas(variable, plot = TRUE)
```

**Arguments**

|          |  |
|----------|--|
| variable | a numeric vector.  |
| plot     | logical; TRUE (default) Returns the plot of all periods exhibiting seasonality and the variable level reference. |

**Value**

Returns a matrix of all periods exhibiting less coefficient of variance than the variable with "all.periods"; and the single period exhibiting the least coefficient of variance versus the variable with "best.period".  
If no seasonality is detected, NNS.seas will return ("No Seasonality Detected").

**Author(s)**

Fred Viole, OVVO Financial Systems

## References

Viola, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments"  
<http://amzn.com/1490523995>

## Examples

```
set.seed(123)
x <- rnorm(100)

## To call strongest period based on coefficient of variance:
NNS.seas(x)$best.period
```

---

|         |                     |
|---------|---------------------|
| NNS.SSD | <i>NNS SSD Test</i> |
|---------|---------------------|

---

## Description

Bi-directional test of second degree stochastic dominance using lower partial moments.

## Usage

```
NNS.SSD(x, y)
```

## Arguments

|   |                   |
|---|-------------------|
| x | a numeric vector. |
| y | a numeric vector. |

## Value

Returns one of the following SSD results: "X SSD Y", "Y SSD X", or "NO SSD EXISTS".

## Author(s)

Fred Viola, OVVO Financial Systems

## References

Viola, F. and Nawrocki, D. (2016) "LPM Density Functions for the Computation of the SD Efficient Set." Journal of Mathematical Finance, 6, 105-126. <http://www.scirp.org/Journal/PaperInformation.aspx?PaperID=63817>.

## Examples

```
set.seed(123)
x <- rnorm(100) ; y <- rnorm(100)
NNS.SSD(x, y)
```

---

|             |                                     |
|-------------|-------------------------------------|
| NNS.SSD.uni | <i>NNS SSD Test uni-directional</i> |
|-------------|-------------------------------------|

---

### Description

Uni-directional test of second degree stochastic dominance using lower partial moments used in SD Efficient Set routine.

### Usage

```
NNS.SSD.uni(x, y)
```

### Arguments

|   |                   |
|---|-------------------|
| x | a numeric vector. |
| y | a numeric vector. |

### Value

Returns (1) if "X SSD Y", else (0).

### Author(s)

Fred Viole, OVVO Financial Systems

### References

Viole, F. and Nawrocki, D. (2016) "LPM Density Functions for the Computation of the SD Efficient Set." Journal of Mathematical Finance, 6, 105-126. <http://www.scirp.org/Journal/PaperInformation.aspx?PaperID=63817>.

### Examples

```
set.seed(123)
x <- rnorm(100) ; y <- rnorm(100)
NNS.SSD.uni(x, y)
```

---

|           |                  |
|-----------|------------------|
| NNS.stack | <i>NNS Stack</i> |
|-----------|------------------|

---

### Description

Prediction model using the predictions of the NNS base models [NNS.reg](#) as features (i.e. meta-features) for the stacked model.

### Usage

```
NNS.stack(IVs.train, DV.train, IVs.test = NULL,
  obj.fn = expression(sum((predicted - actual)^2)), objective = "min",
  CV.size = NULL, folds = 5, order = NULL, norm = NULL,
  method = c(1, 2), dim.red.method = "cor", status = TRUE,
  ncores = NULL)
```

**Arguments**

|                             |   |
|-----------------------------|---|
| <code>IVs.train</code>      | a vector, matrix or data frame of variables of numeric or factor data types.  |
| <code>DV.train</code>       | a numeric or factor vector with compatible dimensions to ( <code>IVs.train</code> ).  |
| <code>IVs.test</code>       | a vector, matrix or data frame of variables of numeric or factor data types with compatible dimensions to ( <code>IVs.train</code> ).   |
| <code>obj.fn</code>         | expression; <code>expression(sum((predicted - actual)^2))</code> (default) Sum of squared errors is the default objective function. Any <code>expression()</code> using the specific terms <code>predicted</code> and <code>actual</code> can be used.  |
| <code>objective</code>      | options: ("min", "max") "min" (default) Select whether to minimize or maximize the objective function <code>obj.fn</code> .   |
| <code>CV.size</code>        | numeric [0, 1]; NULL (default) Sets the cross-validation size if ( <code>IVs.test = NULL</code> ). Defaults to 0.25 for a 25 percent random sampling of the training set under ( <code>CV.size = NULL</code> ).   |
| <code>folds</code>          | integer; <code>folds = 5</code> (default) Select the number of cross-validation folds.  |
| <code>order</code>          | integer; NULL (default) Sets the order for <a href="#">NNS.reg</a> , where ( <code>order = 'max'</code> ) is the k-nearest neighbors equivalent.  |
| <code>norm</code>           | options: ("std", "NNS", NULL); NULL (default) 3 settings offered: NULL, "std", and "NNS". Selects the norm parameter in <a href="#">NNS.reg</a> .   |
| <code>method</code>         | numeric options: (1, 2); Select the NNS method to include in stack. ( <code>method = 1</code> ) selects <a href="#">NNS.reg</a> ; ( <code>method = 2</code> ) selects <a href="#">NNS.reg</a> dimension reduction regression. Defaults to <code>method = c(1, 2)</code> , including both NNS regression methods in the stack.   |
| <code>dim.red.method</code> | options: ("cor", "NNS.dep", "NNS.caus", "all") method for determining synthetic $X^*$ coefficients. ( <code>dim.red.method = "cor"</code> ) (default) uses standard linear correlation for weights. ( <code>dim.red.method = "NNS.dep"</code> ) uses <a href="#">NNS.dep</a> for nonlinear dependence weights, while ( <code>dim.red.method = "NNS.caus"</code> ) uses <a href="#">NNS.caus</a> for causal weights. ( <code>dim.red.method = "all"</code> ) averages all methods for further feature engineering. |
| <code>status</code>         | logical; TRUE (default) Prints status update message in console.  |
| <code>ncores</code>         | integer; value specifying the number of cores to be used in the parallelized subroutine <a href="#">NNS.reg</a> . If NULL (default), the number of cores to be used is equal to half the number of cores of the machine - 1.  |

**Value**

Returns a vector of fitted values for the dependent variable test set for all models.

- "`NNS.reg.n.best`" returns the optimum "`n.best`" parameter for the [NNS.reg](#) multivariate regression. "`SSE.reg`" returns the SSE for the [NNS.reg](#) multivariate regression.
- "`OBJfn.reg`" returns the `obj.fn` for the [NNS.reg](#) regression.
- "`NNS.dim.red.threshold`" returns the optimum "`threshold`" from the [NNS.reg](#) dimension reduction regression.
- "`OBJfn.dim.red`" returns the `obj.fn` for the [NNS.reg](#) dimension reduction regression.
- "`reg`" returns [NNS.reg](#) output.
- "`dim.red`" returns [NNS.reg](#) dimension reduction regression output.
- "`stack`" returns the output of the stacked model.

**Note**

If character variables are used, transform them first to factors using `as.factor`, or `data.matrix` to ensure overall dataset is numeric. A multifunction `sapply` can also be applied to the overall dataset: `data <- sapply(data, function(x){as.factor(x) ; as.numeric(x)})`. Then run `NNS.stack` with transformed variables.

Missing data should be handled prior as well using `na.omit` or `complete.cases` on the full dataset.

If error received:

```
"Error in is.data.frame(x) : object 'RP' not found"
```

reduce the CV.size.

**Author(s)**

Fred Viole, OVVO Financial Systems

**References**

Viole, F. (2016) "Classification Using NNS Clustering Analysis" <https://ssrn.com/abstract=2864711>

**Examples**

```
## Using 'iris' dataset where test set [IVs.test] is 'iris' rows 141:150.
## Not run:
NNS.stack(iris[1:140, 1:4], iris[1:140, 5], IVs.test = iris[141:150, 1:4])

## Using 'iris' dataset to determine [n.best] and [threshold] with no test set.
NNS.stack(iris[, 1:4], iris[, 5])

## Selecting NNS.reg and dimension reduction techniques.
NNS.stack(iris[1:140, 1:4], iris[1:140, 5], iris[141:150, 1:4], method = c(1, 2))
## End(Not run)
```

---

NNS.term.matrix

*NNS Term Matrix*

---

**Description**

Generates a term matrix for text classification use in `NNS.reg`.

**Usage**

```
NNS.term.matrix(x, oos = NULL, names = FALSE)
```

**Arguments**

|       |   |
|-------|---|
| x     | Text A two column dataset should be used. Concatenate text from original sources to comply with format. Also note the possibility of factors in "DV", so "as.numeric(as.character(...))" is used to avoid issues. |
| oos   | Out-of-sample text dataset to be classified.  |
| names | Column names for "IV" and "oos". Defaults to FALSE.   |

**Value**

Returns the text as independent variables "IV" and the classification as the dependent variable "DV". Out-of-sample independent variables are returned with "OOS".

**References**

Viole, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments"  
<http://amzn.com/1490523995>

**Examples**

```
x <- data.frame(cbind(c("sunny", "rainy"), c(1, -1)))
NNS.term.matrix(x)

### Concatenate Text with space separator, cbind with "DV"
x <- data.frame(cbind(c("sunny", "rainy"), c("windy", "cloudy"), c(1, -1)))
x <- data.frame(cbind(paste(x[, 1], x[, 2], sep = " "), as.numeric(as.character(x[, 3]))))
NNS.term.matrix(x)

### NYT Example
## Not run:
require(RTextTools)
data(NYTimes)

### Concatenate Columns 3 and 4 containing text, with column 5 as DV
NYT=data.frame(cbind(paste(NYTimes[, 3], NYT[, 4], sep = " "),
                        as.numeric(as.character(NYTimes[, 5]))))
NNS.term.matrix(NYT)
## End(Not run)
```

---

NNS.TSD

---

*NNS TSD Test*


---

**Description**

Bi-directional test of third degree stochastic dominance using lower partial moments.

**Usage**

```
NNS.TSD(x, y)
```

**Arguments**

|   |                   |
|---|-------------------|
| x | a numeric vector. |
| y | a numeric vector. |

**Value**

Returns one of the following TSD results: "X TSD Y", "Y TSD X", or "NO TSD EXISTS".

**Author(s)**

Fred Viole, OVVO Financial Systems

## References

Viole, F. and Nawrocki, D. (2016) "LPM Density Functions for the Computation of the SD Efficient Set." Journal of Mathematical Finance, 6, 105-126. <http://www.scirp.org/Journal/PaperInformation.aspx?PaperID=63817>.

## Examples

```
set.seed(123)
x <- rnorm(100) ; y <- rnorm(100)
NNS.TSD(x, y)
```

---

NNS.TSD.uni

*NNS TSD Test uni-directional*


---

## Description

Uni-directional test of third degree stochastic dominance using lower partial moments used in SD Efficient Set routine.

## Usage

```
NNS.TSD.uni(x, y)
```

## Arguments

|   |                   |
|---|-------------------|
| x | a numeric vector. |
| y | a numeric vector. |

## Value

Returns (1) if "X TSD Y", else (0).

## Author(s)

Fred Viole, OVVO Financial Systems

## References

Viole, F. and Nawrocki, D. (2016) "LPM Density Functions for the Computation of the SD Efficient Set." Journal of Mathematical Finance, 6, 105-126. <http://www.scirp.org/Journal/PaperInformation.aspx?PaperID=63817>.

## Examples

```
set.seed(123)
x <- rnorm(100) ; y <- rnorm(100)
NNS.TSD.uni(x, y)
```



---

|           |                              |
|-----------|------------------------------|
| PM.matrix | <i>Partial Moment Matrix</i> |
|-----------|------------------------------|

---

### Description

This function generates a co-partial moment matrix for the specified co-partial moment.

### Usage

```
PM.matrix(LPM.degree, UPM.degree, target, variable, pop.adj = FALSE)
```

### Arguments

|            |   |
|------------|---|
| LPM.degree | integer; Degree for variable below target deviations. (degree = 0) is frequency, (degree = 1) is area.  |
| UPM.degree | integer; Degree for variable above target deviations. (degree = 0) is frequency, (degree = 1) is area.  |
| target     | numeric; Typically the mean of Variable X for classical statistics equivalences, but does not have to be. (Vectorized) (target = "mean") will set the target as the mean of every variable. |
| variable   | a numeric matrix or data.frame.   |
| pop.adj    | logical; FALSE (default) Adjusts the sample co-partial moment matrices for population statistics.   |

### Value

Matrix of partial moment quadrant values. Uncalled quadrants will return a matrix of zeros.

### Note

For divergent asymmetrical "D.LPM" and "D.UPM" matrices, matrix is D.LPM(column,row,...).

### Author(s)

Fred Viole, OVVO Financial Systems

### References

Viole, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments"  
<http://amzn.com/1490523995>

### Examples

```
set.seed(123)
x <- rnorm(100) ; y <- rnorm(100) ; z <- rnorm(100)
A <- cbind(x,y,z)
PM.matrix(LPM.degree = 1, UPM.degree = 1, target = "mean", variable = A)

## Calling Individual Partial Moment Quadrants
cov.mtx <- PM.matrix(LPM.degree = 1, UPM.degree = 1, target = "mean", variable = A)
cov.mtx$cupm
```

```
## Full covariance matrix  
cov.mtx$cov.matrix
```

---

UPM

*Upper Partial Moment*

---

### Description

This function generates a univariate upper partial moment for any degree or target.

### Usage

```
UPM(degree, target, variable)
```

### Arguments

|          |   |
|----------|---|
| degree   | integer; (degree = 0) is frequency, (degree = 1) is area.             |
| target   | numeric; Typically set to mean, but does not have to be. (Vectorized) |
| variable | a numeric vector.   |

### Value

UPM of variable

### Author(s)

Fred Viole, OVVO Financial Systems

### References

Viole, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments"  
<http://amzn.com/1490523995>

### Examples

```
set.seed(123)  
x <- rnorm(100)  
UPM(0, mean(x), x)
```

---

|           |                                   |
|-----------|-----------------------------------|
| UPM.ratio | <i>Upper Partial Moment RATIO</i> |
|-----------|-----------------------------------|

---

## Description

This function generates a standardized univariate upper partial moment for any degree or target.

## Usage

```
UPM.ratio(degree, target, variable)
```

## Arguments

|          |   |
|----------|---|
| degree   | integer; (degree = 0) is frequency, (degree = 1) is area.             |
| target   | numeric; Typically set to mean, but does not have to be. (Vectorized) |
| variable | a numeric vector.   |

## Value

Standardized UPM of variable

## Author(s)

Fred Viole, OVVO Financial Systems

## References

Viole, F. and Nawrocki, D. (2013) "Nonlinear Nonparametric Statistics: Using Partial Moments"  
<http://amzn.com/1490523995>

## Examples

```
set.seed(123)
x <- rnorm(100)
UPM.ratio(0, mean(x), x)

## Joint Upper CDF
## Not run:
x <- rnorm(5000) ; y <- rnorm(5000)
plot3d(x, y, Co.UPM(0, 0, sort(x), sort(y), x, y), col = "blue", xlab = "X", ylab = "Y",
zlab = "Probability", box = FALSE)

## End(Not run)
```

---

`UPM.VaR`*UPM VaR*

---

**Description**

Generates an upside VaR based on the Upper Partial Moment ratio

**Usage**

```
UPM.VaR(percentile, degree, x)
```

**Arguments**

|                         |  |
|-------------------------|--|
| <code>percentile</code> | numeric [0, 1]; The percentile for right-tail VaR.   |
| <code>degree</code>     | integer; (degree = 0) for discrete distributions, (degree = 1) for continuous distributions. |
| <code>x</code>          | a numeric vector.  |

**Value**

Returns a numeric value representing the point at which "percentile" of the area of x is below.

**Examples**

```
set.seed(123)
x <- rnorm(100)

## For 95th percentile VaR (right-tail)
UPM.VaR(0.95, 0, x)
```

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