

# Package ‘MonoPoly’

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**Type** Package

**Title** Functions to Fit Monotone Polynomials

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**Description** Functions for fitting monotone polynomials to data.  
Detailed discussion of the methodologies used can be  
found in Murray, Mueller and Turlach (2013)  
<doi:10.1007/s00180-012-0390-5> and Murray, Mueller and  
Turlach (2016) <doi:10.1080/00949655.2016.1139582>.

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coef.monpol	<i>Extract Model Coefficients</i>
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---

## Description

coef method for 'monpol' objects.

## Usage

```
## S3 method for class 'monpol'
coef(object, scale = c("original", "fitted"), type = c("beta", "monpar"), ...)
```

## Arguments

object	A 'monpol' object.
scale	Extract coefficients on the original scale of the data or on the scale used during fitting.
type	Extract coefficients in the 'beta' parameterisation of the polynomial or for the monotone parameterisation used in the algorithm.
...	Additional optional arguments. At present no optional arguments are used.

## Details

This is the `coef` method for objects inheriting from class "monpol".

## Value

Coefficients extracted from the model object object.

## Author(s)

Berwin A Turlach <Berwin.Turlach@gmail.com>

---

`curvPol`*Evaluating the Curvature of Polynomials*

---

**Description**

Function to evaluate the curvature of polynomials

**Usage**

```
curvPol(x, beta)
```

**Arguments**

<code>x</code>	numerical values at which to evaluate the curvature of polynomials, can be provided in a vector, matrix, array or data frame
<code>beta</code>	numerical vector containing the coefficient of the polynomial

**Value**

The result of evaluating the curvature of the polynomial at the values in `x`, returned in the same dimension as `x` has.

**Author(s)**

Berwin A Turlach <Berwin.Turlach@gmail.com>

**Examples**

```
beta <- c(1,2,1)

x <- 0:10
curvPol(x, beta)
str(curvPol(x, beta))

x <- cbind(0:10, 10:0)
curvPol(x, beta)
str(curvPol(x, beta))

x <- data.frame(x=0:10, y=10:0)
curvPol(x, beta)
str(curvPol(x, beta))
```

---

`evalPol`*Evaluating Polynomials*

---

**Description**

Function to evaluate polynomials in a numerical robust way using the Horner scheme

**Usage**

```
evalPol(x, beta)
```

**Arguments**

<code>x</code>	numerical values at which to evaluate polynomials, can be provided in a vector, matrix, array or data frame
<code>beta</code>	numerical vector containing the coefficient of the polynomial

**Value**

The result of evaluating the polynomial at the values in `x`, returned in the same dimension as `x` has.

**Author(s)**

Berwin A Turlach <Berwin.Turlach@gmail.com>

**Examples**

```
beta <- c(1,2,1)

x <- 0:10
evalPol(x, beta)
str(evalPol(x, beta))

x <- cbind(0:10, 10:0)
evalPol(x, beta)
str(evalPol(x, beta))

x <- data.frame(x=0:10, y=10:0)
evalPol(x, beta)
str(evalPol(x, beta))
```

---

fitted.monpol	<i>Extract Model Fitted Values</i>
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---

**Description**

fitted method for 'monpol' objects.

**Usage**

```
## S3 method for class 'monpol'  
fitted(object, scale = c("original", "fitted"), ...)
```

**Arguments**

object	A 'monpol' object.
scale	Extract fitted values on the original scale of the data or on the scale used during fitting.
...	Additional optional arguments. At present no optional arguments are used.

**Details**

This is the `fitted` method for objects inheriting from class "monpol".

**Value**

Fitted values extracted from the model object object.

**Author(s)**

Berwin A Turlach <Berwin.Turlach@gmail.com>

---

hawkins	<i>hawkins</i>
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---

**Description**

This data gives x and y variables for the data published in Hawkins' 1994 article. This data was originally simulated from a standard cubic polynomial with equally spaced x values between -1 and 1.

**Format**

A data frame with 50 simulated observations on the following 2 variables.

y a numeric vector

x a numeric vector

**Source**

Hawkins, D. M. (1994) Fitting monotonic polynomials to data. *Computational Statistics* **9**(3): 233–247.

**Examples**

```
data(hawkins)
```

---

ismonotone	<i>Check whether a polynomial is monotone</i>
------------	---

---

**Description**

Function to check whether a polynomial is montone over a given interval.

**Usage**

```
ismonotone(object, ...)

## S3 method for class 'monpol'
ismonotone(object, a = -Inf, b = Inf, EPS = 1e-06, ...)

## Default S3 method:
ismonotone(object, a = -Inf, b = Inf, EPS = 1e-06, ...)
```

**Arguments**

object	Either an object of class ‘ monpol ’ or a numeric vector containing the coefficient of the polynomial.
a	Lower limit of the interval over which the polynomial should be montone.
b	Upper limit of the interval over which the polynomial should be montone.
EPS	Numerical precision, values with absolute value smaller than EPS are treated as zero.
...	Further arguments passed to or from other methods.

**Value**

TRUE or FALSE depending on whether the polynomial is montone over (a,b) or not.

Note that due to numerical precision issues it is possible that a polynomial that should be monotone is declared to be not monotone.

**Author(s)**

Kevin Murray <Kevin.Murray@uwa.edu.au>  
Berwin A Turlach <Berwin.Turlach@gmail.com>

## Examples

```
fit <- monpol(y~x, w0)
ismonotone(fit)

beta <- c(1,0,2) ## the polynomial 1 + 2*x^2
ismonotone(beta)
ismonotone(beta, a=0)
ismonotone(beta, b=0)
```

---

model.matrix.monpol    *Construct Design Matrices*

---

## Description

model.matrix creates a design (or model) matrix for ‘monpol’ objects.

## Usage

```
## S3 method for class 'monpol'
model.matrix(object, scale = c("original", "fitted"), ...)
```

## Arguments

object	A ‘monpol’ object.
scale	Create design matrix on the original scale of the data or on the scale used during fitting.
...	Additional optional arguments. At present no optional arguments are used.

## Details

This is the `model.matrix` method for objects inheriting from class “monpol”.

## Value

Design matrix created from the model object object.

## Author(s)

Berwin A Turlach <Berwin.Turlach@gmail.com>

monpol

*Monotone Polynomials***Description**

Determine the least-squares estimates of the parameters of a monotone polynomial

**Usage**

```
monpol(formula, data, subset, weights, na.action,
       degree = 3, K, start,
       a = -Inf, b=Inf,
       trace = FALSE, plot.it = FALSE,
       control = monpol.control(),
       algorithm = c("Full", "Hawkins", "BCD", "CD1", "CD2"),
       ptype = c("SOS", "Elphinstone", "EHH", "Penttila"),
       ctype = c("cge0", "c2"),
       monotone,
       model=FALSE, x=FALSE, y=FALSE)
```

**Arguments**

formula	an object of class " <b>formula</b> " (or one that can be coerced to that class): a symbolic description of the model to be fitted.
data	an optional data frame, list or environment (or object coercible by <code>as.data.frame</code> to a data frame) containing the variables in the model. If not found in data, the variables are taken from <code>environment(formula)</code> , typically the environment from which <code>monpol</code> is called.
subset	an optional vector specifying a subset of observations to be used in the fitting process.
weights	an optional vector of weights to be used in the fitting process. Should be <code>NULL</code> or a numeric vector.
na.action	a function which indicates what should happen when the data contain NAs. The default is set by the <code>na.action</code> setting of <code>options</code> , and is <code>na.fail</code> if that is unset. The ‘factory-fresh’ default is <code>na.omit</code> . Another possible value is <code>NULL</code> , no action. Value <code>na.exclude</code> can be useful.
degree	positive integer, a polynomial with highest power equal to degree will be fitted to the data.
K	non-negative integer, a polynomial with highest power $2K + 1$ will be fitted to the data.
start	optional starting value for the iterative fitting.
a,b	polynomial should be monotone on the interval from a to b. If either parameter is finite, parameterisation “SOS” has to be used.
trace	print out information about the progress of the iterative fitting at the start and then every <code>trace</code> iterations.



<code>plot.it</code>	plot the data and initial fit, then plot current fit every <code>plot.it</code> iterations.
<code>control</code>	settings that control the iterative fit; see <a href="#">monpol.control</a> for details.
<code>algorithm</code>	algorithm to be used. It is recommended to use either “Full” or “Hawkins”; see both papers in ‘References’ for details.
<code>ptype</code>	parameterisation to be used. It is recommended to use the “SOS” parameterisation; see the 2016 paper in ‘References’ for details.
<code>ctype</code>	parameterisation to be used; see paper in ‘References’ for details.
<code>monotone</code>	only used for parameterisation “SOS” to enforce the kind of monotonicity desired over the interval $[a, b]$ , should be “increasing” or “decreasing”.
<code>model, x, y</code>	logicals. If TRUE the corresponding components of the fit (the model frame, the model matrix, the response, the QR decomposition) are returned.

## Details

A `monpol` object is a type of fitted model object. It has methods for the generic function [coef](#), [fitted](#), [formula](#), [logLik](#), [model.matrix](#), [predict](#), [print](#), [residuals](#).

The parameterisation type “SOS” with the “Full” algorithm is currently the recommended fitting procedure and is discussed in the 2016 paper in ‘References’. For this parameterisation the argument `ctype` is ignored.

The “Hawkins” algorithm is also recommended and discussed in both papers in the ‘References’.

The parameterisations “Elphinstone”, “EHH” and “Pentilla”, for which the argument “ctype” defines a further variation of parameterisation, work together with algorithms “Full”, “BCD”, “CD1” and “CD2”. These parameterisations and algorithms are discussed in the 2013 paper in ‘References’.

## Value

`monpol` returns an object of class `"monpol"`

## Author(s)

Berwin A Turlach <Berwin.Turlach@gmail.com>

## References

Murray, K., Müller, S. and Turlach, B.A. (2016). Fast and flexible methods for monotone polynomial fitting, *Journal of Statistical Computation and Simulation* **86**(15): 2946–2966, doi: [10.1080/00949655.2016.1139582](https://doi.org/10.1080/00949655.2016.1139582).

Murray, K., Müller, S. and Turlach, B.A. (2013). Revisiting fitting monotone polynomials to data, *Computational Statistics* **28**(5): 1989–2005, doi: [10.1007/s0018001203905](https://doi.org/10.1007/s0018001203905).

## Examples

```
monpol(y~x, w0)
```

---

monpol.control                      *Control the Iterations in monpol*

---

### Description

Allow the user to set some characteristics of the monpol monotone polynomial fitting algorithm.

### Usage

```
monpol.control(maxiter = 1000, tol = 1e-05,  
              tol1=1e-10, tol2=1e-07, tolqr=1e-07)
```

### Arguments

maxiter	A positive integer specifying the maximum number of iterations allowed, used in all algorithms.
tol	A positive numeric value specifying an absolute tolerance for determining whether entries in the gradient are zero for algorithms 'Full', 'BCD', 'CD1' and 'CD2'.
tol1	A positive numeric value, used in algorithm 'Hawkins'. Any number not smaller than -tol1 is deemed to be non-negative.
tol2	A positive numeric value, used in algorithm 'Hawkins'. Any number whose absolute value is smaller than tol2 is taken to be zero.
tolqr	A positive numeric value, used in algorithm 'Hawkins' as tolerance for the QR factorisation of the design matrix.

### Value

A list with exactly five components:

```
maxiter  
tol  
tol1  
tol2  
tolqr
```

with meanings as explained under 'Arguments'.

### Author(s)

Berwin A Turlach <Berwin.Turlach@gmail.com>

### See Also

[monpol](#), [monpol.fit](#), [qr](#)

**Examples**

```
monpol.control(maxiter = 2000)
monpol.control(tolqr = 1e-10)
```

---

monpol.fit

*Monotone Polynomials*


---

**Description**

This is the basic computing engine called by `monpol` used to fit monotonic polynomials. These should usually *not* be used directly unless by experienced users.

**Usage**

```
monpol.fit(x, y, w, K=1, start, trace = FALSE, plot.it = FALSE,
           control = monpol.control(),
           algorithm = c("Full", "Hawkins", "BCD", "CD1", "CD2"),
           ptype = c("Elphinstone", "EHH", "Penttila"),
           ctype = c("cge0", "c2"))
SOSpol.fit(x, y, w = NULL, deg.is.odd, K, start, a, b,
           monotone = c("increasing", "decreasing"),
           trace = FALSE, plot.it = FALSE, type,
           control = monpol.control())
```

**Arguments**

<code>x</code>	vector containing the observed values for the regressor variable.
<code>y</code>	vector containing the observed values for the response variable; should be of same length as <code>x</code> .
<code>w</code>	optional vector of weights; should be of the same length as <code>x</code> if specified.
<code>deg.is.odd, K</code>	“deg.is.odd” is a logical, “K” is a non negative integer. If “deg.is.odd” is TRUE then a polynomial with highest power $2K + 1$ will be fitted to the data, otherwise the highest order will be $2K$ .
<code>start</code>	optional starting value for the iterative fitting.
<code>a, b, type</code>	polynomial should be monotone on the interval from <code>a</code> to <code>b</code> ; “type” should be 0 if neither of the boundaries is finite, 1 if <code>a</code> is finite but not <code>b</code> and 2 if both boundaries are finite.
<code>monotone</code>	force the desired monotonicity in case the default choice is wrong.
<code>trace</code>	print out information about the progress of the iterative fitting at the start and then every <code>trace</code> iterations.
<code>plot.it</code>	plot the data and initial fit, then plot current fit every <code>plot.it</code> iterations.
<code>control</code>	settings that control the iterative fit; see <code>monpol.control</code> for details.
<code>algorithm</code>	algorithm to be used; see <code>monpol</code> for details.
<code>ptype</code>	parameterisation to be used; see <code>monpol</code> for details.
<code>ctype</code>	parameterisation to be used; see <code>monpol</code> for details.

**Value**

a list with components

par	the fitted parameters.
grad	the gradient of the objective function at the fitted parameters.
beta	the coefficients of the fitted polynomial in the ‘beta’ parameterisation; on the fitted scale.
RSS	the value of the objective function; on the fitted scale.
niter	number of iterations.
converged	indicates whether algorithm has converged.
ptype	input parameter ptype.
ctype	input parameter ctype.
beta.raw	the coefficients of the fitted polynomial in the ‘beta’ parameterisation; on the original scale.
fitted.values	the fitted values; on the fitted scale.
residuals	the residuals; on the fitted scale.
K	input parameter K.
minx	the minimum value in the vector x.
sclx	the difference between the maximum and minimum values in the vector x.
miny	the minimum value in the vector y.
sclx	the difference between the maximum and minimum values in the vector y.
algorithm	input parameter algorithm.

**Author(s)**

Berwin A Turlach <Berwin.Turlach@gmail.com>

**References**

- Murray, K., Müller, S. and Turlach, B.A. (2016). Fast and flexible methods for monotone polynomial fitting, *Journal of Statistical Computation and Simulation* **86**(15): 2946–2966, doi: [10.1080/00949655.2016.1139582](https://doi.org/10.1080/00949655.2016.1139582).
- Murray, K., Müller, S. and Turlach, B.A. (2013). Revisiting fitting monotone polynomials to data, *Computational Statistics* **28**(5): 1989–2005, doi: [10.1007/s0018001203905](https://doi.org/10.1007/s0018001203905).

**See Also**

[monpol](#) which you should use for fitting monotonic polynomials unless you know better.

---

predict.monpol	<i>Predicting from Monotone Polynomial Fits</i>
----------------	---

---

**Description**

predict.monpol produces predicted values, obtained by evaluating the monotone polynomial in the frame newdata.

**Usage**

```
## S3 method for class 'monpol'
predict(object, newdata, scale = c("original", "fitted"), ...)
```

**Arguments**

object	A 'monpol' object.
newdata	A named list or data frame in which to look for variables with which to predict. If newdata is missing the fitted values at the original data points are returned.
scale	Predict values on the original scale of the data or on the scale used during fitting. Data in newdata is assumed to be on the indicated scale.
...	Additional optional arguments. At present no optional arguments are used.

**Details**

This is the `predict` method for objects inheriting from class "monpol".

**Value**

predict.monpol produces a vector of predictions.

**Author(s)**

Berwin A Turlach <Berwin.Turlach@gmail.com>

---

print.monpol	<i>Printing Monotone Polynomials</i>
--------------	--------------------------------------

---

**Description**

print method for 'monpol' objects.

**Usage**

```
## S3 method for class 'monpol'
print(x, digits = max(3, getOption("digits") - 3), ...)
```

**Arguments**

x                    A 'monpol' object.  
 digits              minimal number of *significant* digits, see [print.default](#).  
 ...                  Additional optional arguments. At present only the additional arguments for [coef.monpol](#) are used.

**Details**

This is the [print](#) method for objects inheriting from class "monpol".

**Value**

x returned invisibly.

**Author(s)**

Berwin A Turlach <Berwin.Turlach@gmail.com>

---

residuals.monpol            *Extract Model Residuals*

---

**Description**

residuals method for 'monpol' objects.

**Usage**

```
## S3 method for class 'monpol'
residuals(object, scale = c("original", "fitted"), ...)
```

**Arguments**

object                A 'monpol' object.  
 scale                 Extract residuals on the original scale of the data or on the scale used during fitting.  
 ...                    Additional optional arguments. At present no optional arguments are used.

**Details**

This is the [residuals](#) method for objects inheriting from class "monpol".

**Value**

Residuals extracted from the model object object.

**Author(s)**

Berwin A Turlach <Berwin.Turlach@gmail.com>

---

w0

*Simulated w0 data used in Murray et al. (2013)*

---

### Description

This data set gives simulated data from the function

$$y = 0.1x^3 + e$$

for  $e \sim N(0, 0.01^2)$  and  $x$  evenly spaced between -1 and 1.

### Format

A data frame with 21 observations on the following 2 variables.

y a numeric vector

x a numeric vector

### Source

Murray, K., Müller, S. and Turlach, B.A. (2013). Revisiting fitting monotone polynomials to data, *Computational Statistics* **28**(5): 1989–2005, doi: [10.1007/s0018001203905](https://doi.org/10.1007/s0018001203905).

### Examples

```
str(w0)
plot(y~x, w0)
monpol(y~x, w0)
```

---

w2

*Simulated w2 data used in Murray et al. (2013)*

---

### Description

Simulated data from the function

$$y_{ij} = 4\pi - x_i + \cos\left(x_i - \frac{\pi}{2}\right) + e_{ij}$$

for  $x_i = 0, 1, \dots, 12$ ;  $n_i = 5$  for  $i = 0$  and  $n_i = 3$  otherwise;  $e_{ij} \sim N(0, 0.5^2)$

### Format

A data frame with 41 observations on the following 2 variables.

y a numeric vector

x a numeric vector

**Source**

Murray, K., Müller, S. and Turlach, B.A. (2013). Revisiting fitting monotone polynomials to data, *Computational Statistics* **28**(5): 1989–2005, doi: [10.1007/s0018001203905](https://doi.org/10.1007/s0018001203905).

**Examples**

```
str(w2)
plot(y~x, w2)
monpol(y~x, w2)
monpol(y~x, w2, K=2)
```



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