

# Package ‘higrad’

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**Type** Package

**Title** Statistical Inference for Online Learning and Stochastic  
Approximation via HiGrad

**Version** 0.1.0

**Description** Implements the Hierarchical Incremental GRADient Descent (HiGrad) algorithm,  
a first-order algorithm for finding the minimizer of a function in online learning just like stochastic  
gradient descent (SGD).

In addition, this method attaches a confidence interval to assess the uncertainty of its predictions.

See Su and Zhu (2018) <[doi:10.48550/arXiv.1802.04876](https://doi.org/10.48550/arXiv.1802.04876)> for details.

**License** GPL-3

**Encoding** UTF-8

**LazyData** true

**RoxygenNote** 6.0.1

**Imports** Matrix

**NeedsCompilation** no

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## Contents

higrad . . . . .	2
plot.higrad . . . . .	4
predict.higrad . . . . .	4
print.higrad . . . . .	5

<b>Index</b>	<b>6</b>
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higrad

*Fitting HiGrad***Description**

higrad is used to implement hierarchical incremental gradient descent (HiGrad), an algorithm that conducts statistical inference for online learning.

**Usage**

```
higrad(x, y, model = "lm", nsteps = nrow(x), nsplits = 2, nthreads = 2,
       step.ratio = 1, n0 = NA, skip = 0, eta = 1/2, alpha = 1/2,
       burnin = round(nsteps/10), start = rnorm(ncol(x), 0, 0.01),
       replace = FALSE, track = FALSE)
```

**Arguments**

x	input matrix of features. Each row is an observation vector, and each column is a feature.
y	response variable. Quantitative for model = "lm". For model = "logistic" it should be a factor with two levels.
model	type of model to fit. Currently only linear regression ("lm") and logistic regression ("logistic") are supported.
nsteps	total number of steps. This is equivalent to the number of queries made to get a noisy evaluation of the gradient.
nsplits	number of splits in the HiGrad tree.
nthreads	numbers of threads each previous thread is split into. Either a number (equal split size throughout) or a vector.
step.ratio	ratio of the lengths of the threads from the two adjacent levels (the latter one divided by the previous). Either a number (equal ratio throughout) or a vector.
n0	length of the 0th-level thread.
skip	number of steps to skip when estimating the coefficients by averaging.
eta	constant in front of the step size. See Details for the formula of the step size.
alpha	exponent of the step size. See Details for the formula of the step size.
burnin	number of steps as the burn-in period. The burn-in period is not accounted for in the total budget nsteps.
start	starting values of the coefficients.
replace	logical; whether or not to sample the data with replacement.
track	logical; whether or not to store the entire path for plotting.

## Details

HiGrad is designed to conduct statistical inference for online learning, without incurring additional computational cost compared with the vanilla stochastic gradient descent (SGD). The HiGrad procedure begins by performing SGD iterations for a while and then split the single thread into a few, and this procedure hierarchically operates in this fashion along each thread. With predictions provided by multiple threads in place, a t-based confidence interval is constructed by de-correlating predictions using covariance structures given by the Ruppert–Polyak averaging scheme. In order to implement HiGrad, a configuration of the tree structure needs to be specified. The default setting is a binary tree with 2 splits. The step size is set to be  $\eta \alpha t^{-\alpha}$ .

## Value

An object with S3 class higrad.

coefficients	estimate of the coefficients.
coefficients.bootstraps	matrix of estimates of the coefficients along each HiGrad threads.
model	model type.
Sigma0	covariance structure $\Sigma$ of the estimates.
track	entire path of the estimates along each thread. Can be used for diagnostic and check for convergence.

## References

Weijie Su and Yuancheng Zhu. (2018) *Statistical Inference for Online Learning and Stochastic Approximation via Hierarchical Incremental Gradient Descent*. <https://arxiv.org/abs/1802.04876>.

## See Also

See `print.higrad`, `plot.higrad`, `predict.higrad` for other methods for the higrad class.

## Examples

```
# fitting linear regression on a simulated dataset
n <- 1e3
d <- 10
sigma <- 0.1
theta <- rep(1, d)
x <- matrix(rnorm(n * d), n, d)
y <- as.numeric(x %*% theta + rnorm(n, 0, sigma))
fit <- higrad(x, y, model = "lm")
print(fit)
# predict for 10 new samples
newx <- matrix(rnorm(10 * d), 10, d)
pred <- predict(fit, newx)
pred
```

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plot.higrad	<i>Plot a higrad Object</i>
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**Description**

Produces a coefficient paths for a fitted higrad object.

**Usage**

```
## S3 method for class 'higrad'
plot(x, ...)
```

**Arguments**

x	a fitted object of class higrad.
...	additional graphical parameters.

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predict.higrad	<i>Obtain Prediction and Confidence Intervals From a HiGrad Fit</i>
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**Description**

predict can be applied with a higrad object to obtain predictions and confidence intervals.

**Usage**

```
## S3 method for class 'higrad'
predict(object, newx, alpha = 0.05, type = "link",
        prediction.interval = FALSE, ...)
```

**Arguments**

object	a fitted object of class higrad.
newx	matrix of new values for x at which predictions are to be made.
alpha	significance level. The confidence level of the interval is thus 1 - alpha.
type	type of prediction required. Type "link" gives the linear predictors for "logistic"; for "lm" models it gives the fitted values. Type "response" gives the fitted probabilities for "logistic"; for "lm" type "response" is equivalent to type "link".
prediction.interval	logical; indicator of whether prediction intervals should be returned instead of confidence intervals.
...	other prediction options.

**Value**

A list with components

pred	predicted values.
upper	upper limit of the confidence/prediction intervals.
lower	lower limit of the confidence/prediction intervals.

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print.higrad	<i>Print a higrad Object</i>
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**Description**

Print the coefficients estimates obtained by HiGrad.

**Usage**

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

**Arguments**

x	a fitted object of class higrad.
...	additional print arguments.

# Index

`higrad`, 2

`plot.higrad`, 3, 4

`predict.higrad`, 3, 4

`print.higrad`, 3, 5