

# Package ‘growthrate’

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**Title** Bayesian reconstruction of growth velocity

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**Description** A nonparametric empirical Bayes method for recovering gradients (or growth velocities) from observations of smooth functions (e.g., growth curves) at isolated time points.

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growthrate-package      *Recovery of gradients from sparsely observed functional data*

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### Description

A nonparametric empirical Bayes method for recovering gradients (or growth velocities) from observations of smooth functions (e.g., growth curves) at isolated time points.

### References

Lopez-Pintado, S. and McKeague, I. W. (2013). *Recovering gradients from sparsely observed functional data*. Biometrics 69, 396-404 (2013). <http://www.columbia.edu/~im2131/ps/growthrate-package-reference.pdf>

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cv.growth      *cross validation error*

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### Description

Computes the cross validation error resulting from the removal of the data at a given interior observation time as a function of the infinitesimal standard deviation  $\sigma$  on a grid of  $k$  equispaced values in the interval  $[a, b]$ .

### Usage

```
cv.growth(data, tobs, d, K, a, b, r)
```

### Arguments

data	Input matrix of size $N$ (subjects) times $n$ (observation times). Each column contains the heights (of all subjects) at a given observation time, each row contains the heights (at the observation times) for a given subject.
tobs	Row vector of $n$ observation times (in increasing order, same for each subject).
d	Number of points on the fine time-grid (between the first and last observation times in tobs) at which the posterior means and covariances are computed.
K	Number of points on the grid for $\sigma$ .
a	Minimum value for $\sigma$ (positive).
b	Maximum value for $\sigma$ (strictly larger than a).
r	Index of the interior observation time in tobs removed in the cross-validation.

### Details

The data for the  $r$ th observation time (for a given  $1 < r < n$ ) are removed and the mean squared error of the reconstructed data at that time point computed over the grid for  $\sigma$ .



**Arguments**

data	As in growth.
tobs	As in growth.

**Value**

YI	An N times (n-1) matrix with rows given by the values of the one-sided difference quotients $y_i, i = 1 \dots, n - 1$ for the N subjects.
Xtilda	An n by N matrix with columns given by the values of the second-order difference quotients $\mathbf{y}$ for the N subjects.

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growth	<i>recovery of growth velocities</i>
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**Description**

Computes the mean function and covariance kernel (over a fine grid of equispaced time points) of the posterior growth velocity for each subject, based on growth data (e.g., heights) at fixed observation times.

**Usage**

```
growth(data, tobs, sigma, d)
```

**Arguments**

data	Input matrix of size N (subjects) times n (observation times). Each column contains the heights (of all subjects) at a given observation time, each row contains the heights (at the observation times) for a given subject.
tobs	Row vector of n observation times (in increasing order, same for each subject).
sigma	A positive scalar representing the infinitesimal standard deviation of the tied-down Brownian motion in the prior. Can be selected by cross-validation.
d	Number of time points on the fine grid.

**Details**

The Bayesian reconstruction implemented here uses a prior growth velocity model that is specified by a general multivariate normal distribution at the n fixed observation times, and a tied-down Brownian motion (having infinitesimal standard deviation specified by sigma) between the observation times.

The prior mean and prior precision matrix at the observation times are estimated using the data on N subjects. Clime (constrained L1 minimization) provides the estimate of the prior precision matrix, with the clime constraint parameter lambda selected by 5-fold cross validation using the likelihood loss function.

**Value**

muhatcurve	Posterior means of the growth velocities (for each subject) on the fine grid tgrid. An N (subjects) times d matrix.
Khat	Posterior covariance kernel of the growth velocities on the fine grid tgrid. A d times d matrix (the same for every subject).
tgrid	The fine grid of d equispaced-time points (between the first and last observation times in tobs) at which the posterior means and covariances are computed.

**Author(s)**

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**References**

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**Examples**

```
## Not run:
## example using the height data provided in the package
## there are 7 observation times (age in years):
data(height_data);
tobs=c(0,1/3,2/3,1,3,4,7);
d=200;
sigma=1;
g=growth(height_data,tobs,sigma,d);

## Plot of the posterior mean and credible interval for a specific individual
indiv=1;
## posterior standard deviation (same for all subjects):
postsd=sqrt(diag(g$Khat));
plot(g$tgrid,g$muhatcurve[indiv,],type='l',
xlab="Age (years)",ylab="Growth velocity (cms/year)");
lines(g$tgrid,g$muhatcurve[indiv,]);
lines(g$tgrid,g$muhatcurve[indiv,]+2*postsd,lty=2);
lines(g$tgrid,g$muhatcurve[indiv,]-2*postsd,lty=2);

## Plot of a draw from the posterior growth velocity for a specific individual:
draw=rmvnorm(n=1, mean=g$muhatcurve[indiv,], sigma=g$Khat, method="chol");
plot(g$tgrid,draw,type='l',xlab="Age (years)",ylab="Growth
velocity (cms/year)");

## End(Not run)
```

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height_data	<i>height data</i>
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**Description**

The heights of 532 girls at birth, four, eight, and twelve months, and three, four, and seven years of age.

**Usage**

```
data(height_data)
```

**Format**

A matrix with 532 observations on 7 variables (height at each age).

**References**

Lopez-Pintado, S. and McKeague, I. W. (2013). *Recovering gradients from sparsely observed functional data*. Biometrics 69, 396-404 (2013). <http://www.columbia.edu/~im2131/ps/growthrate-package-reference.pdf>

**Examples**

```
data(height_data)
```

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Khatf	<i>posterior covariance kernel</i>
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**Description**

Internal function. Finds the posterior covariance kernel on the fine grid tgrid (same for every subject); see Section 2 of the referenced article for further details.

**Usage**

```
Khatf(tgrid, tobs, sigma, Sigmahat)
```

**Arguments**

tgrid	The fine grid of $d$ equispaced-time points (between the first and last observation times in tobs) at which the posterior means and covariances are computed.
tobs	Row vector of $n$ observation times (in increasing order, same for each subject).
sigma	Infinitesimal standard deviation of the tied-down Brownian motion in the prior.
Sigmahat	Posterior covariance at the observation times tobs (same for every subject).

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new.growth	<i>recovery of growth velocity for a new subject</i>
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### Description

Computes the posterior mean and covariance kernel for a new subject having data at observation times newtobs different from tobs (apart from the first and the last). growth needs to be run first.

### Usage

```
new.growth(newdata, newtobs, sigma, d, muhatcurve, Khat, tgrid)
```

### Arguments

newdata	Row vector of p heights for the new subject.
newtobs	Row vector of p observation times for the new subject (in increasing order; must include the first and last time points in tobs).
sigma	Infinitesimal standard deviation of the Brownian motion prior (same as in growth).
d	Number of time points on the fine grid.
muhatcurve	Output from growth.
Khat	Output from growth.
tgrid	The fine grid (output from growth).

### Value

muhatcurvenew	Posterior mean (on tgrid) for the new subject.
Khatnew	Posterior covariance kernel (on tgrid) for the new subject.

### Author(s)

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### References

Lopez-Pintado, S. and McKeague, I. W. (2013). *Recovering gradients from sparsely observed functional data*. Biometrics 69, 396-404 (2013). <http://www.columbia.edu/~im2131/ps/growthrate-package-reference.pdf>

**Examples**

```
## Not run:
## example using the height data provided in the package
##   (after first running growth to obtain the output g):
## suppose a new subject has 5 observation times (including 0 and 7)
data(height_data);
tobs=c(0,1/3,2/3,1,3,4,7);
d=200;
sigma=1;
g=growth(height_data,tobs,sigma,d);

newtobs=c(0, 2, 3, 5, 7);
newdata=t(as.vector(c(50,70,87,100,115)));
ng=new.growth(newdata,newtobs,sigma,d,g$muhatcurve,g$Khat,g$tgrid);

## plot of the posterior mean growth velocity for the new subject:
plot(g$tgrid,ng$muhatcurvenew,xlab="Age (years)",ylab="Growth
velocity (cms/year)");

## End(Not run)
```

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posteriordistribcurve *posterior mean*

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**Description**

Internal function. Finds the posterior mean on the fine grid tgrid for every subject.

**Usage**

```
posteriordistribcurve(muhatmatrix, Sigmahat, sigma, tobs, d, YI)
```

**Arguments**

muhatmatrix	Posterior mean at the observation times tobs obtained from posteriorobs.
Sigmahat	Posterior covariance at the observation times tobs obtained from posteriorobs.
sigma	Infinitesimal standard deviation of the tied-down Brownian motion in the prior.
tobs	Row vector of n observation times (in increasing order, same for each subject).
d	Number of time points on the fine grid.
YI	An N times (n-1) matrix with rows given by the values of $y_i, i = 1 \dots, n - 1$ for the N subjects.

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posteriorobs                      *posterior mean and covariance at observation times*

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### Description

Internal function. Finds the posterior mean and covariance at the observation times `tobs`, for every subject; see Section 2 of the referenced article for further details.

### Usage

```
posteriorobs(Sigma0inv, sigma, muprior, Xtilda, tobs, YI)
```

### Arguments

<code>Sigma0inv</code>	Prior precision matrix at the observation times <code>tobs</code> .
<code>sigma</code>	Infinitesimal standard deviation of the tied-down Brownian motion in the prior.
<code>muprior</code>	Prior mean at the observation times <code>tobs</code> .
<code>Xtilda</code>	An $n$ by $N$ matrix with columns given by the values of $\mathbf{y}$ for the $N$ subjects.
<code>tobs</code>	Row vector of $n$ observation times (in increasing order, same for each subject).
<code>YI</code>	An $N$ times $(n-1)$ matrix with rows given by the values of $y_i, i = 1 \dots, n - 1$ for the $N$ subjects.

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priormeanobs                      *prior mean*

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### Description

Internal function. Finds the sample mean of the  $n$ -vector  $\mathbf{y}$  for use in specifying the prior mean  $\boldsymbol{\mu}_0$ ; see Section 2 of the referenced article for further details.

### Usage

```
priormeanobs(YI, tobs)
```

### Arguments

<code>YI</code>	The $N$ times $(n-1)$ matrix with rows being the values of $y_i, i = 1 \dots, n - 1$ for the $N$ subjects
<code>tobs</code>	Row vector of $n$ observation times (in increasing order, same for each subject).

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