Package ‘Rgbp’

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Title Bayesian Hierarchical Modeling using Generalized Stein’s Harmonic Prior

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Depends sn, mnormt

Description Bayesian Hierarchical modeling for Gaussian (GRIMM), Binomial (BRIMM) and Poisson (PRIMM) data using generalized Stein’s harmonic prior.

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BugReports https://github.com/jyklly/gbp/issues

R topics documented:

`baseball` *Baseball Data*

Description

Batting averages of 18 major league players through their first 45 official at bats of the 1970 season. These batting averages were published weekly in the New York Times, and by April 26, 1970.

Usage

`data(baseball)`

Format

A data set of 18 players with 10 covariates:

`FirstName` each player's first name

`LastName` each player's last name

`At.Bats` number of times batted

`Hits` each player's number of hits among 45 at bats

`BattingAverage` batting averages among 45 at bats

`RemainingAt.Bats` number of times batted after 45 at bats until the end of season

`RemainingAverage` batting averages after 45 at bats until the end of season

`SeasonAt.Bats` number of times batted over the whole season

`SeasonHits` each player's number of hits over the whole season

`SeasonAverage` batting averages over the whole season

Source

Efron, B. and Morris, C. (1975). Data Analysis Using Stein's Estimator and its Generalizations. *Journal of the American Statistical Association*. **70**. 311-319.

Examples

```
data(baseball)
z <- baseball$Hits
n <- baseball$At.Bats

####################################################################################
# We do not have any covariates and do not know a mean of the prior distribution. #
####################################################################################

#########
# BRIMM #
#########

b <- gbp(z, n, model = "br")
b
summary(b)
```

```
plot(b)

#########
# PRIMM #
#########

p <- gbp(z, n, model = "pr")
p
summary(p)
plot(p)
```

---

coverage *Estimating Coverage Probability*

Description

coverage estimates Rao-Blackwellized and unbiased coverage probabilities.

Usage

```
coverage(gbp.object, A.or.r, reg.coef, covariates, mean.PriorDist, nsim = 10)
```

Arguments

gbp.object	a resultant object of gbp function.
A.or.r	(optional) a numeric value of *A* for GRIMM or of *r* for BRIMM (and PRIMM). Designating this argument should come with other arguments, for example, (A.or.r, reg.coef, covariates (if any)) or (A.or.r, mean.PriorDist).
reg.coef	(optional) a (*m* by 1) vector for regression coefficients, β, where *m* is the number of regression coefficients including an intercept.
covariates	(optional) a (*k* by *t*) matrix of covariates without a column of ones for an intercept, where *k* is the number of groups (or units) in a dataset and *t* is the number of covariates (t $\geq$ 1). If gbp fits an intercept in the regression, *t = (m - 1)*.
mean.PriorDist	(optional) a numeric value for the mean of (second-level) prior distribution.
nsim	number of simulations (datasets to be generated). Default is 10.

Details

As for the argument gbp.object, if the result of gbp is designated to b, for example "b <- gbp(z, n, model = "br")", the argument gbp.object indicates this b.

Data generating process is based on a second-level hierarchical model. The first-level is a distribution of observed data (Likelihood) and the second-level is a conjugate prior distribution on the first-level parameter. Covariates appear in the second-level because covariates are obtainable before we observe data.

To be specific, the first hierarchy has $f(y_j \mid \theta_j)$ proportional to Lik(θ_j). And the second hierarchy has a conjugate prior distribution such as $p(\theta_j \mid \mu_{0j},\ A$ (or r)) = $p[\mu_{0j},\ A]$ for GRIMM, $p[\mu_{0j},\ \mu_{0j}/r]$ for PRIMM, and $p[\mu_{0j},\ \mu_{0j} * (1-\mu_{0j})/(r+1)]$ for BRIMM, where $g(\mu_{0j})\ =\ x_j'\beta$.

Two elements of the square braket indicate [mean, variance] of that distribution and *g* is a link function.

From now on, the subscript *i* means *i*-th simulation and *j* indicates *j*-th group (or unit).

In order to generate pseudo-datasets, `coverage` needs parameters of prior distribution, *A* (or *r*), β (`reg.coef`), and *X* (`covariates`) (if any), or *A* (or *r*) and μ_0 (`mean.PriorDist`). From here, we have four options to run `gbp`.

First, if any values related to the prior distribution are not designated like `coverage(b, nsim = 10)`, then `coverage` will regard estimated values in `b` (=`gbp.object`) as given true values when it generates bunch of pseudo datasets. After sampling a (*k* by 1) vector θ_i from the prior distribution determined by those estimated values in `b` (=`gbp.object`), `coverage` creates an *i*-th pseudo-dataset based on θ_i just sampled.

Second, `coverage` allows us to designate different true values in generating datasets, for example `coverage(b, A.or.r = 15, reg.coef = 3, nsim = 100)` assuming we do not have any covariate and do not know a mean of the prior distribution a priori. One value designated in `reg.coef` will be used to calculate the mean of second-level distribution by $g(\mu_0) = \beta_0 = 3$. Then, `coverage` samples a (*k* by 1) vector θ_i from the prior distribution determined by designated values, `A.or.r` and `reg.coef` (only intercept term). Sampling *i*-th pseudo-data is based on θ_i just sampled.

Third, `coverage` enables us to designate different true values in generating datasets like `coverage(b, A.or.r = 15, reg.coef = c(3, -1), covariates = X, nsim = 100)` when we have one covariate (can be more than one but `reg.coef` should reflect on the number of regression coefficients including an intercept term) without any knowledge about the mean of prior distribution a priori. For reference, a covariate matrix, `X`, should not include a column of ones for an intercept term in the regression and the mean of prior distribution will be set as $g(\mu_{0j}) = x_j'\beta$, where x_j is (1, *j*-th row of `X`)'. Then, `coverage` samples a (*k* by 1) vector θ_i from the prior distribution determined by designated values, `A.or.r`, `reg.coef`, and `covariates`. Sampling *i*-th pseudo-data is based on θ_i just sampled.

Lastly, `coverage` provides us a way to designate different true values in generating datasets like `coverage(b, A.or.r = 15, mean.PriorDist = 0.45, nsim = 100)` when we know the mean of prior distribution a priori. Then, `coverage` samples a (*k* by 1) vector θ_i from the prior distribution determined by designated values, `A.or.r` and `mean.PriorDist`. The *i*-th Pseudo-datasets are generated based on θ_i just sampled.

The unbiased estimator of coverage probability in *j*-th group (or unit) is a sample mean of indicators over all simulated datasets. The *j*-th indicator in *i*-th simulation is 1 if the estimated interval of the *j*-th group on *i*-th simulated dataset contains a true parameter θ_{ij} that generated the observed value of the *j*-th group in the *i*-th dataset.

Rao-Blackwellized estimator is an expectation of the unbiased estimator described above given a sufficient statistic, *y*.

Value

`coverageRB` estimated Rao-Blackwellized coverage probability for each group (or unit) averaged over all simulations.

`coverage10` estimated unbiased coverage probability for each group (or unit) averaged over all simulations.

`average.coverageRB`
average value over `coverageRB`.

`average.coverage10`
average value over `coverage10`.

`minimum.coverageRB`
minimum value among `coverageRB`.

minimum.coverage10
: minimum value among coverage10.

raw.resultRB
: all the Rao-Blackwellized coverage probabilities for every group and for every simulation.

raw.result10
: all the unbiased coverage probabilities for every group and for every simulation.

Author(s)

Joseph Kelly, Carl Morris, and Hyungsuk Tak

References

Christiansen, C. and Morris, C. (1997). Hierarchical Poisson Regression Modeling. *Journal of the American Statistical Association*. **92**. 618-632.

Examples

```
# Loading datasets
data(schools)

# baseball data where z is Hits and n is AtBats
z <- c(18, 17, 16, 15, 14, 14, 13, 12, 11, 11, 10, 10, 10, 10, 10,  9,  8,  7)
n <- c(45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45)
x1 <- rep(c(-1, 0, 1), 6)

y <- schools$y
se <- schools$se
x2 <- rep(c(-1, 0, 1, 2), 2)

####################################################################################
# If we do not have any covariate and do not know a mean of the prior distribution #
####################################################################################

#########
# GRIMM #
#########

g <- gbp(y, se)

### when we want to simulated psuedo datasets considering the estimated values as true ones
coverage(g, nsim = 10)

### when we want to simulate psuedo datasets based on different values of A and of a regression
### coefficient (intercept), not using estimated values as true ones
coverage(g, A.or.r = 9, reg.coef = 10, nsim = 10)

#########
# BRIMM #
#########

b <- gbp(z, n, model = "br")

### when we want to simulated psuedo datasets considering the estimated values as true ones
coverage(b, nsim = 10)
```

```
### when we want to simulate psuedo datasets based on different values of r and of a regression
### coefficient (intercept), not using estimated values as true ones
coverage(b, A.or.r = 60, reg.coef = -1, nsim = 10)

#########
# PRIMM #
#########

p <- gbp(z, n, model = "pr")

### when we want to simulated psuedo datasets considering the estimated values as true ones
coverage(p, nsim = 10)

### when we want to simulate psuedo datasets based on different values of r and of a regression
### coefficient (intercept), not using estimated values as true ones
coverage(p, A.or.r = 60, reg.coef = -5, nsim = 10)

##################################################################################
# If we have one covariate and do not know a mean of the prior distribution yet, #
##################################################################################

#########
# GRIMM #
#########

g <- gbp(y, se, x2, model = "gr")

### when we want to simulated psuedo datasets considering the estimated values as true ones
coverage(g, nsim = 10)

### when we want to simulate psuedo datasets based on different values of A, of regression
### coefficients, and of covariate, not using estimated values as true ones
coverage(g, A.or.r = 9, reg.coef = c(10, 1), covariates = x2, nsim = 10)
### two values of reg.coef are for beta0 and beta1

#########
# BRIMM #
#########

b <- gbp(z, n, x1, model = "br")

### when we want to simulated psuedo datasets considering the estimated values as true ones
coverage(b, nsim = 10)

### when we want to simulate psuedo datasets based on different values of r, of regression
### coefficients, and of covariate, not using estimated values as true ones
coverage(b, A.or.r = 60, reg.coef = c(-1, 0), covariates = x1, nsim = 10)
### two values of reg.coef are for beta0 and beta1

#########
# PRIMM #
#########

p <- gbp(z, n, x1, model = "pr")

### when we want to simulated psuedo datasets considering the estimated values as true ones
coverage(p, nsim = 10)
```

```
### when we want to simulate psuedo datasets based on different values of r, of regression
### coefficients, and of covariate, not using estimated values as true ones
coverage(p, A.or.r = 60, reg.coef = c(-2, 0), covariates = x1, nsim = 10)
### two values of reg.coef are for beta0 and beta1

################################################
# If we know a mean of the prior distribution, #
################################################

#########
# GRIMM #
#########

g <- gbp(y, se, mean.PriorDist = 8)

### when we want to simulated psuedo datasets considering the estimated values as true ones
coverage(g, nsim = 10)

### when we want to simulate psuedo datasets based on different values of A and of 2nd level
### mean as true ones, not using estimated values as true ones
coverage(g, A.or.r = 9, mean.PriorDist = 5, nsim = 10)

#########
# BRIMM #
#########

b <- gbp(z, n, mean.PriorDist = 0.265, model = "br")

### when we want to simulated psuedo datasets considering the estimated values as true ones
coverage(b, nsim = 10)

### when we want to simulate psuedo datasets based on different values of r and of 2nd level
### mean as true ones, not using estimated values as true ones
coverage(b, A.or.r = 60, mean.PriorDist = 0.3, nsim = 10)

#########
# PRIMM #
#########

p <- gbp(z, n, mean.PriorDist = 0.265, model = "pr")

### when we want to simulated psuedo datasets considering the estimated values as true ones
coverage(p, nsim = 10)

### when we want to simulate psuedo datasets based on different values of r and of 2nd level
### mean as true ones, not using estimated values as true ones
coverage(p, A.or.r = 60, mean.PriorDist = 0.3, nsim = 10)
```

---

gbp *Fitting Bayesian Hierarchical Models*

Description

gbp is used to fit Bayesian hierarchical models for Gaussian (GRIMM), Binomial (BRIMM), and

Poisson (PRIMM) data using generalized Stein's harmonic prior for good frequentist repeated sampling property.

Usage

```
## Default S3 method:
gbp(x, y, covariates, mean.PriorDist, model = "gr", intercept = TRUE, Alpha = 0.95)
```

Arguments

`x`	a (*k* by 1) vector of *k* groups' sample means for GRIMM or of each group's number of successful trials for BRIMM and PRIMM, where *k* is the number of groups (or units) in a dataset.
`y`	a (*k* by 1) vector composed of the standard errors of all groups for GRIMM or of each group's total number of trials for BRIMM and PRIMM.
`covariates`	(optional) a (*k* by *t*) matrix of covariates without a column of ones for an intercept term, where *k* is the number of groups (or units) in a dataset and *t* is the number of covariates (t $\geq$ 1).
`mean.PriorDist`	(optional) a numeric value for the second-level mean parameter, *i.e.* the mean of prior distribution, if you know this value a priori.
`model`	a character string indicating which hierarchical model to fit. "gr" for Gaussian data, "br" for Binomial, and "pr" for Poisson. Default is "gr"
`intercept`	`TRUE` or `FALSE` flag indicating whether an intercept should be included in the regression. Default is `TRUE`.
`Alpha`	a `float` between 0 and 1 to estimate 100*Alpha% intervals. Default is 0.95.

Details

gbp fits a Bayesian hierarchical model using generalized Stein's harmonic prior which enables good frequentist repeated sampling properties. The first-level is a distribution of observed data (likelihood) and the second-level is a conjugate prior distribution on the first-level parameter.

To be specific, for Normal data, gbp constructs a two-level Normal-Normal multilevel model (σ_j^2 is assumed to be known and subscript *j* indicates *j*-th group (or unit) in a dataset):

$$(y_j \mid \theta_j) \ \sim \ indep\, N(\theta_j, \sigma_j^2)$$

$$(\theta_j \mid A, \ \mu_{0j}) \ \sim \ indep\, N(\mu_{0j}, \ A)$$

$$\mu_{0j} \ = \ x_j'\beta$$

for $j = 1, \ldots, k$.

For Poisson data, gbp builds a two-level Poisson-Gamma multilevel model (a square bracket below indicates [mean, variance] of distribution):

$$(z_j \mid \theta_j) \ \sim \ indep\, Pois(n_j\theta_j)$$

$$(\theta_j \mid r, \ \mu_{0j}) \ \sim \ indep\, Gam(r\mu_{0j}, scale = 1/r) \ \sim \ indep\, Gam[\mu_{0j}, \mu_{0j}/r]$$

$$log(\mu_{0j}) \ = \ x_j'\beta$$

for $j = 1, \ldots, k$.

For Binomial data, gbp sets a two-level Binomial-Beta multilevel model:

$$(z_j \mid \theta_j) \sim indep\, Bin(n_j, \theta_j)$$

$$(\theta_j \mid r, \mu_{0j}) \sim indep\, Beta(r\mu_{0j},\ r(1-\mu_{0j})) \sim indep\, Beta[\mu_{0j},\ \mu_{0j}(1-\mu_{0j})\ /\ (r+1)]$$

$$logit(\mu_{0j}) = x_j'\beta$$

for $j = 1, \ldots, k$.

Theoretically, generalized Stein's harmonic prior is Uniform on the second level variance component (variance of the prior distribution), *i.e.*, *dA* for GRIMM and *d(1 / r)* (= $\frac{dr}{r^2}$) for BRIMM and PRIMM, leading to proper posterior distributions.

Under this setting, the argument `x` in gbp is a (*k* by 1) vector of *k* groups' sample means (*y* used in the Normal-Normal model above) for GRIMM or of each group's number of successful trials (*z*) for BRIMM and PRIMM, where *k* is the number of groups (or units) in a dataset.

The argument y (not *y* used in the Normal-Normal model above) in gbp is a (*k* by 1) vector composed of the standard errors (σ) of all groups for GRIMM or of each group's total number of trials (*n*) for BRIMM and PRIMM.

As for two optional arguments, `covariates` and `mean.PriorDist`, there are three feasible combinations of them to run gbp. The first situation is when we do not have any covariate and do not know a mean of the prior distribution (μ_0) a priori. In this case, assigning none of two optional arguments, such as "`gbp(z, n, model = "br")`", will lead to a correct model. gbp will automatically fit a regression with only an intercept term to estimate a common mean of the prior distribution (exchangeability).

The second situation is when we have some covariates (a *k* by *t* matrix, where *t* $\geq$ 1) and do not know a mean of the prior distribution (μ_0) a priori. In this case, assigning a *k* by *t* matrix (each column corresponds to one covariate), *X*, such as "`gbp(z, n, X, model = "pr")`", will lead to a right model. Default of gbp is to fit a regression inclduing an intercept term to estimate a mean of the prior distribution. Double exchangeability will hold in this case.

The last case is when we know a mean of the prior distribution (μ_0) a priori. Now, we do not need to estimate regression coefficients at all because we know a true value of μ_0 (strong assumption). Designating this value into the argument of gbp like "`gbp(y, se, mean.PriorDist = 3, model = "gr")`" is enough to account for it. For reference, `mean.PriorDist` has a stronger priority than `covariates`, which means that when both arguments are designated, gbp will fit a hierarchical model using the known mean of prior distribution, `mean.PriorDist`.

When it comes to estimating hyper-parameters, (*A* or *r*) and β, gbp uses a mixture model with θ integrated out, first searching for a value that maximizes the marginal posterior distribution of α (= log(*A*) for GRIMM or -log(*r*) for BRIMM and PRIMM), and then looking for an estimate of β (possibly a vector) that maximizes its posterior distribution (Likelihood) given previously estimated α. `optim` is used for maximizing marginal and conditional posterior distributions.

gbp returns an object of class "gbp" which provides the functions `plot`, `print`, and `summary`.

Value

An object of class gbp comprises of:

`sample.mean`	sample mean of each group
`se`	if GRIMM, standard error of each group
`n`	if BRIMM and PRIMM, total number of trials of each group
`prior.mean`	numeric if entered, NA if not entered
`prior.mean.hat`	estimate of prior mean by a regression if prior mean is not assigned a priori

shrinkage	shrinkage estimate of each group
sd.shrinkage	standard deviation of shrinkage estimate
post.mean	posterior mean of each group
post.sd	posterior standard deviation of each group
post.intv.low	lower bound of 100*Alpha% posterior interval
post.intv.upp	upper bound of 100*Alpha% posterior interval
model	"gr" for GRIMM, "br" for BRIMM, and "pr" for PRIMM
X	a covariate vector or matrix if designated. NA if not
beta.new	regression coefficient estimates
beta.var	estimated variance matrix of regression coefficient
intercept	whether TRUE or FALSE
a.new	alpha estimate
a.var	variance of alpha estimate

Author(s)

Joseph Kelly, Carl Morris, and Hyungsuk Tak

References

Morris, C. and Tang, R. (2011). Estimating Random Effects via Adjustment for Density Maximization. *Statistical Science*. **26**. 271-287.

Morris, C. and Lysy, M. (2012). Shrinkage Estimation in Multilevel Normal Models. *Statistical Science*. **27**. 115-134.

Examples

```
# Loading datasets
data(schools)

# baseball data where z is Hits and n is at bats
z <- c(18, 17, 16, 15, 14, 14, 13, 12, 11, 11, 10, 10, 10, 10, 10,  9,  8,  7)
n <- c(45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45)

# an arbitrary covariate for baseball data
x1 <- rep(c(-1, 0, 1), 6)

y <- schools$y
se <- schools$se

# an arbitrary covariate for schools data
x2 <- rep(c(-1, 0, 1, 2), 2)

#####################################################################################
# If we do not have any covariates and do not know a mean of the prior distribution #
#####################################################################################

#########
# GRIMM #
#########
```

```
g <- gbp(y, se)
g
summary(g)
plot(g)

### when we want to simulated pseudo datasets considering the estimated values as true ones
coverage(g, nsim = 10)

### when we want to simulate psuedo datasets based on different values of A and of a regression
### coefficient (intercept), not using estimated values as true ones
coverage(g, A.or.r = 9, reg.coef = 10, nsim = 10)

#########
# BRIMM #
#########

b <- gbp(z, n, model = "br")
b
summary(b)
plot(b)

### when we want to simulated pseudo datasets considering the estimated values as true ones
coverage(b, nsim = 10)

### when we want to simulate psuedo datasets based on different values of r and of a regression
### coefficient (intercept), not using estimated values as true ones
coverage(b, A.or.r = 60, reg.coef = -1, nsim = 10)

#########
# PRIMM #
#########

p <- gbp(z, n, model = "pr")
p
summary(p)
plot(p)

### when we want to simulated pseudo datasets considering the estimated values as true ones
coverage(p, nsim = 10)

### when we want to simulate psuedo datasets based on different values of r and of a regression
### coefficient (intercept), not using estimated values as true ones
coverage(p, A.or.r = 60, reg.coef = -5, nsim = 10)

########################################################################################
# If we have one covariate and do not know a mean of the prior distribution a priori, #
########################################################################################

#########
# GRIMM #
#########

g <- gbp(y, se, x2, model = "gr")
g
summary(g)
plot(g)
```

```
### when we want to simulated psuedo datasets considering the estimated values as true ones
coverage(g, nsim = 10)

### when we want to simulate psuedo datasets based on different values of A, of regression
### coefficients, and of covariate, not using estimated values as true ones
coverage(g, A.or.r = 9, reg.coef = c(10, 1), covariates = x2, nsim = 10)
### two values of reg.coef are for beta0 and beta1

#########
# BRIMM #
#########

b <- gbp(z, n, x1, model = "br")
b
summary(b)
plot(b)

### when we want to simulated pseudo datasets considering the estimated values as true ones
coverage(b, nsim = 10)

### when we want to simulate psuedo datasets based on different values of r, of regression
### coefficients, and of covariate, not using estimated values as true ones
coverage(b, A.or.r = 60, reg.coef = c(-1, 0), covariates = x1, nsim = 10)
### two values of reg.coef are for beta0 and beta1

#########
# PRIMM #
#########

p <- gbp(z, n, x1, model = "pr")
p
summary(p)
plot(p)

### when we want to simulated pseudo datasets considering the estimated values as true ones
coverage(p, nsim = 10)

### when we want to simulate psuedo datasets based on different values of r, of regression
### coefficients, and of covariate, not using estimated values as true ones
coverage(p, A.or.r = 60, reg.coef = c(-2, 0), covariates = x1, nsim = 10)
### two values of reg.coef are for beta0 and beta1

################################################
# If we know a mean of the prior distribution, #
################################################

#########
# GRIMM #
#########

g <- gbp(y, se, mean.PriorDist = 8)
g
summary(g)
plot(g)

### when we want to simulated pseudo datasets considering the estimated values as true ones
```

```
coverage(g, nsim = 10)

### when we want to simulate psuedo datasets based on different values of A and of 2nd level
### mean as true ones, not using estimated values as true ones
coverage(g, A.or.r = 9, mean.PriorDist = 5, nsim = 10)

#########
# BRIMM #
#########

b <- gbp(z, n, mean.PriorDist = 0.265, model = "br")
b
summary(b)
plot(b)

### when we want to simulated pseudo datasets considering the estimated values as true ones
coverage(b, nsim = 10)

### when we want to simulate psuedo datasets based on different values of r and of 2nd level
### mean as true ones, not using estimated values as true ones
coverage(b, A.or.r = 60, mean.PriorDist = 0.3, nsim = 10)

#########
# PRIMM #
#########

p <- gbp(z, n, mean.PriorDist = 0.265, model = "pr")
p
summary(p)
plot(p)

### when we want to simulated pseudo datasets considering the estimated values as true ones
coverage(p, nsim = 10)

### when we want to simulate psuedo datasets based on different values of r and of 2nd level
### mean as true ones, not using estimated values as true ones
coverage(p, A.or.r = 60, mean.PriorDist = 0.3, nsim = 10)
```

`hospital` *Thirty-one Hospital Data*

Description

Medical profiling evaluation of 31 New York hospitals in 1992. We are to consider these as Normally-distributed indices of successful outcome rates for patients at these 31 hospitals following Coronary Artery Bypass Graft (CABG) surgeries. The indices are centered so that the New York statewide average outcome over all hospitals lies near 0. Larger estimates of `y` indicate hospitals that performed better for these surgeries.

Usage

```
data(hospital)
```

Format

A data set of 31 hospitals comprises of:

- y values obtained through a variance stabilizing transformation of the unbiased death rate estimates, d / n, assuming Binomial data. Details in the reference.
- se approximated standard error of y.
- d the number of deaths within a month of CABG surgeries in each hospital
- n total number of patients receiving CABG surgeries (case load) in each hospital

Source

Morris, C. and Lysy, M. (2012). Shrinkage Estimation in Multilevel Normal Models. *Statistical Science*. **27**. 115-134.

Examples

```
data(hospital)

z <- hospital$d
n <- hospital$n
y <- hospital$y
se <- hospital$se

##################################################################################
# We do not have any covariates and do not know a mean of the prior distribution. #
##################################################################################

#########
# GRIMM #
#########

g <- gbp(y, se)
g
summary(g)
plot(g)

#########
# BRIMM #
#########

b <- gbp(z, n, model = "br")
b
summary(b)
plot(b)

#########
# PRIMM #
#########

p <- gbp(z, n, model = "pr")
p
summary(p)
plot(p)
```

plot.gbp *Drawing Shrinkage and Posterior Interval Plots*

Description

plot(gbp.object) draws shrinkage and posterior interval plots

Usage

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

Arguments

x	a resultant object of gbp function.
...	further arguments passed to other methods.

Details

As for the argument x, if the result of gbp is designated to b like "b <- gbp(z, n, model = "br")", the argument x is supposed to be b.

The overall window popping up as a result of plot(b) has three parts. The first part (column) of this window is for a legend describing symbols used in the plots. In the legend, a black circle represents sample mean, a red dot does posterior mean, a blue line does prior mean, a violet line (additional explanation needed).

The second column is about the shrinkage plot and it has two horizontal lines; the observed sample means are on the upper line and the posterior means are on the lower line. (additional explanation is expected of Joey)

The final plot shows interval estimates of all the groups (units) in a dataset. Two short horizontal ticks at both ends of each black vertical line indicate 97.5% and 2.5% quantiles of a posterior distribution for each group (Normal for GRIMM, Gamma for PRIMM, and Beta for BRIMM). Red dots (posterior mean) are between black circles (sample mean) and blue line(s) (prior mean) as a result of shrinkage (regression toward the mean).

Value

Two plots described in *details* will be displayed.

Author(s)

Joseph Kelly, Carl Morris, and Hyungsuk Tak

Examples

```
data(hospital)

z <- hospital$d
n <- hospital$n
y <- hospital$y
se <- hospital$se
```

```
###################################################################################
# We do not have any covariates and do not know a mean of the prior distribution. #
###################################################################################

#########
# GRIMM #
#########

g <- gbp(y, se)
plot(g)

#########
# BRIMM #
#########

b <- gbp(z, n, model = "br")
plot(b)

#########
# PRIMM #
#########

p <- gbp(z, n, model = "pr")
plot(p)
```

---

print.gbp *Displying "gbp" Class*

Description

print.gbp enables users to see a compact group-level (unit-level) estimation result of gbp function.

Usage

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

Arguments

x	a resultant object of gbp function.
...	further arguments passed to other methods.

Details

As for the argument x, if the result of gbp is designated to b like "b <- gbp(z, n, model = "br")", the argument x is supposed to be b.

Users do not need to type "print(b)" but "b" itself is enough to call print.gbp.

Value

`print(gbp.object)` will display

`sample.mean`	sample mean of each group
`se`	if GRIMM, standard error of each group
`n`	if BRIMM and PRIMM, total number of trials of each group
`X`	a covariate vector or matrix if designated. NA if not
`prior.mean`	numeric if entered, NA if not entered
`prior.mean.hat`	estimate of prior mean by a regression if prior mean is not assigned a priori. The variable name on the display will be "prior.mean."
`shrinkage`	shrinkage estimate of each group
`sd.shrinkage`	standard deviation of shrinkage estimate
`post.intv.low`	lower bound of 100*Alpha% posterior interval
`post.mean`	posterior mean of each group
`post.intv.upp`	upper bound of 100*Alpha% posterior interval
`post.sd`	posterior standard deviation of each group

Author(s)

Joseph Kelly, Carl Morris, and Hyungsuk Tak

Examples

```
data(hospital)

z <- hospital$d
n <- hospital$n
y <- hospital$y
se <- hospital$se

###################################################################################
# We do not have any covariates and do not know a mean of the prior distribution. #
###################################################################################

#########
# GRIMM #
#########

g <- gbp(y, se)
g

#########
# BRIMM #
#########

b <- gbp(z, n, model = "br")
b

#########
# PRIMM #
#########
```

```
p <- gbp(z, n, model = "pr")
p
```

---

print.summary.gbp *Displying "summary.gbp" Class*

Description

summary(gbp.object) enables users to see a compact summary of estimation result.

Usage

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

Arguments

x	a resultant object of gbp function.
...	further arguments passed to other methods.

Details

The summary has three parts depending on the model fitted by gbp; Main Summary, Second-level Variance Component Estimation Summary, and Regression Summary (if fitted).

A display of Main Summary changes depending on whether all the groups (units) has the same standard error for GRIMM (or the same total number of trials for BRIMM and PRIMM). If they are not the same, Main Summary lists groups (units) with minimun, median, and maximum values of the standard error for GRIMM (or of the total number of trials for BRIMM and PRIMM). And the last row of Main Summary is about the overall average for all the groups (units) within each column. Note that this last row is not an average over displayed groups (units) above.

If groups (units) have the same standard error for GRIMM (or the same total number of trials for BRIMM and PRIMM), Main Summary lists groups (units) with minimun, median, and maximum values of the sample mean.

For reference, if there are several units with the same median value, they will show up with numbering.

The second part is about the Second-level Variance Component Estimation Summary. To be specific, it shows estimate of α defined as log(A) for GRIMM or -log(r) for BRIMM and PRIMM and its standard deviation. It is actually a posterior mode.

The last part depends on whether gbp fitted a regression or not. For reference, gbp fits a regression if the second-level mean (mean.PriorDist) was not designated. In case, gbp.object includes a regression result, summary(gbp.object) will display the result of resgression fit.

Value

`summary(gbp.object)` shows a compact summary of estimation result such as:

`Main summary`

- **Group w/ min(se or n)** an estimation result of a group (unit) with the minimum standard error for GRIMM or the minimum total number of trials for BRIMM and PRIMM.
- **Group w/ min(sample.mean)** appears instead of `Group w/ min(se or n)` when all the groups (units) have the same standard error for GRIMM or the same total number of trials for BRIMM and PRIMM.
- **Group w/ median(se or n)** an estimation result of group(s) (unit(s)) with the median standard error for GRIMM or the median total number of trials for BRIMM and PRIMM.
- **Group w/ median(sample.mean)** appears instead of `Group w/ median(se or n)` when all the groups (units) have the same standard error for GRIMM or the same total number of trials for BRIMM and PRIMM.
- **Group w/ max(se or n)** an estimation result of a group (unit) with the meximum standard error for GRIMM or the maximum total number of trials for BRIMM and PRIMM.
- **Group w/ max(sample.mean)** appears instead of `Group w/ max(se or n)` when all the groups (units) have the same standard error for GRIMM or the same total number of trials for BRIMM and PRIMM.
- **Mean over all groups** the overall average for all the groups (units) within each column.

`Second-level Variance Component Estimation Summary`

- **alpha.hat** a posterior mode of α defined as log(A) for GRIMM or -log(r) for BRIMM and PRIMM.
- **alpha.hat.sd** standard deviation of alpha.hat.

`Regression Summary (if fitted)`

- **estimate** regression coefficient estimates.
- **se** estimated standard error of regression coefficients.
- **z.val** estimate / se.
- **p.val** two-sided p-values.

Author(s)

Joseph Kelly, Carl Morris, and Hyungsuk Tak

Examples

```
data(hospital)

z <- hospital$d
n <- hospital$n
y <- hospital$y
se <- hospital$se

####################################################################################
# We do not have any covariates and do not know a mean of the prior distribution. #
####################################################################################

#########
```

```
# GRIMM #
#########

g <- gbp(y, se)
summary(g)

#########
# BRIMM #
#########

b <- gbp(z, n, model = "br")
summary(b)

#########
# PRIMM #
#########

p <- gbp(z, n, model = "pr")
summary(p)
```

Rgbp *Fitting Bayesian Hierarchical Models*

Description

Bayesian Hierarchical modeling for Gaussian (GRIMM), Binomial (BRIMM) and Poisson (PRIMM) data using generalized Stein's harmonic prior for good frequentist repeated sampling property.

Details

Package:	Rgbp
Type:	Package
Version:	1.0.0
Date:	2013-03-16
License:	GPL-2

Author(s)

Joseph Kelly, Carl Morris, and Hyungsuk Tak

Maintainer: Joseph Kelly <kelly2@fas.harvard.edu>

References

Morris, C. and Tang, R. (2011). Estimating Random Effects via Adjustment for Density Maximization. *Statistical Science*. **26**. 271-287.

Morris, C. and Lysy, M. (2012). Shrinkage Estimation in Multilevel Normal Models. *Statistical Science*. **27**. 115-134.

Examples

```
# Loading datasets
data(schools)

# baseball data where z is Hits and n is at bats
z <- c(18, 17, 16, 15, 14, 14, 13, 12, 11, 11, 10, 10, 10, 10, 10,  9,  8,  7)
n <- c(45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45, 45)

# an arbitrary covariate for baseball data
x1 <- rep(c(-1, 0, 1), 6)

y <- schools$y
se <- schools$se

# an arbitrary covariate for schools data
x2 <- rep(c(-1, 0, 1, 2), 2)

#####################################################################################
# If we do not have any covariates and do not know a mean of the prior distribution #
#####################################################################################

#########
# GRIMM #
#########

g <- gbp(y, se)
g
summary(g)
plot(g)

### when we want to simulated pseudo datasets considering the estimated values as true ones
coverage(g, nsim = 10)

### when we want to simulate psuedo datasets based on different values of A and of a regression
### coefficient (intercept), not using estimated values as true ones
coverage(g, A.or.r = 9, reg.coef = 10, nsim = 10)

#########
# BRIMM #
#########

b <- gbp(z, n, model = "br")
b
summary(b)
plot(b)

### when we want to simulated pseudo datasets considering the estimated values as true ones
coverage(b, nsim = 10)

### when we want to simulate psuedo datasets based on different values of r and of a regression
### coefficient (intercept), not using estimated values as true ones
coverage(b, A.or.r = 60, reg.coef = -1, nsim = 10)

#########
# PRIMM #
```

```
#########

p <- gbp(z, n, model = "pr")
p
summary(p)
plot(p)

### when we want to simulated pseudo datasets considering the estimated values as true ones
coverage(p, nsim = 10)

### when we want to simulate psuedo datasets based on different values of r and of a regression
### coefficient (intercept), not using estimated values as true ones
coverage(p, A.or.r = 60, reg.coef = -5, nsim = 10)

####################################################################################
# If we have one covariate and do not know a mean of the prior distribution a priori, #
####################################################################################

#########
# GRIMM #
#########

g <- gbp(y, se, x2, model = "gr")
g
summary(g)
plot(g)

### when we want to simulated psuedo datasets considering the estimated values as true ones
coverage(g, nsim = 10)

### when we want to simulate psuedo datasets based on different values of A, of regression
### coefficients, and of covariate, not using estimated values as true ones
coverage(g, A.or.r = 9, reg.coef = c(10, 1), covariates = x2, nsim = 10)
### two values of reg.coef are for beta0 and beta1

#########
# BRIMM #
#########

b <- gbp(z, n, x1, model = "br")
b
summary(b)
plot(b)

### when we want to simulated pseudo datasets considering the estimated values as true ones
coverage(b, nsim = 10)

### when we want to simulate psuedo datasets based on different values of r, of regression
### coefficients, and of covariate, not using estimated values as true ones
coverage(b, A.or.r = 60, reg.coef = c(-1, 0), covariates = x1, nsim = 10)
### two values of reg.coef are for beta0 and beta1

#########
# PRIMM #
#########

p <- gbp(z, n, x1, model = "pr")
```

```
p
summary(p)
plot(p)

### when we want to simulated pseudo datasets considering the estimated values as true ones
coverage(p, nsim = 10)

### when we want to simulate psuedo datasets based on different values of r, of regression
### coefficients, and of covariate, not using estimated values as true ones
coverage(p, A.or.r = 60, reg.coef = c(-2, 0), covariates = x1, nsim = 10)
### two values of reg.coef are for beta0 and beta1

################################################
# If we know a mean of the prior distribution, #
################################################

#########
# GRIMM #
#########

g <- gbp(y, se, mean.PriorDist = 8)
g
summary(g)
plot(g)

### when we want to simulated pseudo datasets considering the estimated values as true ones
coverage(g, nsim = 10)

### when we want to simulate psuedo datasets based on different values of A and of 2nd level
### mean as true ones, not using estimated values as true ones
coverage(g, A.or.r = 9, mean.PriorDist = 5, nsim = 10)

#########
# BRIMM #
#########

b <- gbp(z, n, mean.PriorDist = 0.265, model = "br")
b
summary(b)
plot(b)

### when we want to simulated pseudo datasets considering the estimated values as true ones
coverage(b, nsim = 10)

### when we want to simulate psuedo datasets based on different values of r and of 2nd level
### mean as true ones, not using estimated values as true ones
coverage(b, A.or.r = 60, mean.PriorDist = 0.3, nsim = 10)

#########
# PRIMM #
#########

p <- gbp(z, n, mean.PriorDist = 0.265, model = "pr")
p
summary(p)
plot(p)
```

```
### when we want to simulated pseudo datasets considering the estimated values as true ones
coverage(p, nsim = 10)

### when we want to simulate psuedo datasets based on different values of r and of 2nd level
### mean as true ones, not using estimated values as true ones
coverage(p, A.or.r = 60, mean.PriorDist = 0.3, nsim = 10)
```

`schools` *Eight Schools Data*

Description

Dataset as seen in Rubin (1981) which was an analysis of coaching effects on SAT scores from eight schools.

Usage

```
data(schools)
```

Format

A dataset of 8 schools containing

`y` The observed coaching effect of each school

`se` The standard error of the coaching effect of each school.

Source

Rubin, D. B. (1981). *Estimation in parallel randomized experiments.* Journal of Educational Statistics, 6:377-401.

References

Rubin, D. B. (1981). *Estimation in parallel randomized experiments.* Journal of Educational Statistics, 6:377-401.

Examples

```
data(schools)
```

summary.gbp *Summarizing Estimation Result*

Description

summary.gbp prepares a summary of estimation result saved in the object defined as "gbp" class creating "summary.gbp" class

Usage

```
## S3 method for class 'gbp'
summary(object, ...)
```

Arguments

object	a resultant object of gbp function.
...	further arguments passed to other methods.

Value

summary.gbp prepares below contents:

main	a table to be displayed by summary(gbp.object). print.summary.gbp.
sec.var	a vector containing an estimation result of the second-level variance component. print.summary.gbp.
reg	a vector composed of a summary of regression fit (if fitted). print.summary.gbp.

Author(s)

Joseph Kelly, Carl Morris, and Hyungsuk Tak

Examples

```
data(hospital)

z <- hospital$d
n <- hospital$n
y <- hospital$y
se <- hospital$se

###################################################################################
# We do not have any covariates and do not know a mean of the prior distribution. #
###################################################################################

#########
# GRIMM #
#########

g <- gbp(y, se)
summary(g)

#########
```

```
# BRIMM #
#########

b <- gbp(z, n, model = "br")
summary(b)

#########
# PRIMM #
#########

p <- gbp(z, n, model = "pr")
summary(p)
```

Index