

Package ‘GENMETA’

January 20, 2025

Title Implements Generalized Meta-Analysis Using Iterated Reweighted Least Squares Algorithm

Version 0.2.0

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Description Generalized meta-analysis is a technique for estimating parameters associated with a multiple regression model through meta-analysis of studies which may have information only on partial sets of the regressors. It estimates the effects of each variable while fully adjusting for all other variables that are measured in at least one of the studies. Using algebraic relationships between regression parameters in different dimensions, a set of moment equations is specified for estimating the parameters of a maximal model through information available on sets of parameter estimates from a series of reduced models available from the different studies. The specification of the equations requires a reference dataset to estimate the joint distribution of the covariates. These equations are solved using the generalized method of moments approach, with the optimal weighting of the equations taking into account uncertainty associated with estimates of the parameters of the reduced models. The proposed framework is implemented using iterated reweighted least squares algorithm for fitting generalized linear regression models. For more details about the method, please see pre-print version of the manuscript on generalized meta-analysis by Prosenjit Kundu, Runlong Tang and Nilanjan Chatterjee (2018) <doi:10.1093/biomet/asz030>. The current version (0.2.0) is updated to address some of the stability issues in the previous version (0.1).

Depends R (>= 2.15.3), MASS, graphics

Imports Matrix, magic, pracma

License GPL

Encoding UTF-8

RoxygenNote 7.2.2

Collate 'myoptim.R' 'sign.star.R' 'GENMETA.R' 'GENMETA.control.R'
'GENMETA.summary.R' 'GENMETA.plot.R'

NeedsCompilation no

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Repository CRAN

Date/Publication 2022-12-01 00:50:02 UTC

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GENMETA	<i>Implementing Generalized Meta-analysis</i>
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Description

Generalized Meta-analysis(GENMETA) is an approach for combining information on multivariate regression parameters across multiple different studies which have different, but, possibly overlapping information on subsets of covariates. GENMETA implements the generalized meta-analysis using IRWLS algorithm.

Usage

```
GENMETA(
  study_info,
  ref_dat,
  model,
  variable_intercepts = FALSE,
  initial_val = NULL,
  control = list(epsilon = 1e-06, maxit = 1000)
)
```

Arguments

study_info	<p>a list of lists containing information about the studies; the main list contains a list for each study, which must have the fields:</p> <ul style="list-style-type: none"> • "Coeff": a named numeric vector containing the estimates of regression parameters (including intercept) where the names identify the covariates. For example, <code>names(study_info\$Coeff) <- c("(Intercept)", "Age", "Height", "Weight")</code>. • "Covariance": a matrix containing an estimate of variance-covariance matrix of the regression parameters. This can be NULL if the "Sample_size" is provided. • "Sample_size": a numeric containing sample size of the study. This can be NULL if the "Covariance" is provided.
ref_dat	<p>a data matrix containing all the distinct covariates across studies from a reference set of individuals. This is used for estimating joint distribution of the covariates. The data matrix must have the vector of ones as its first column. The column names of the data matrix should match the names of the covariates from the studies.</p>

<code>model</code>	a description of the type of regression model; this is a character string naming the regression model. The current version is for "logistic" and "linear".
<code>variable_intercepts</code>	an optional logical (applicable only when the model is "logistic"); if TRUE, the intercepts of the true models for each of the studies are assumed to be different. Default is FALSE.
<code>initial_val</code>	an optional numeric vector containing initial values for the maximal model parameters which is needed for the IRWLS algorithm. Default is set to the one obtained from standard meta-analysis of the available estimates for each of the parameters across studies. If one of the studies contain information on all the covariates, then the user can use this study to obtain estimate of the initial vector. See details.
<code>control</code>	an optional list containing the epsilon (positive numeric) and maxiter (positive number) needed for convergence of the algorithm. Default epsilon and maximum iterations are 1e-06 and 1000, respectively. For creating a control argument for GENMETA, see GENMETA.control .

Details

Generalized Meta-analysis (GENMETA) is a tool that allows researchers to quickly build models for multivariate meta-analysis in the presence of disparate covariate information across studies. It is implemented based on mainly two input arguments:

- Information on the model parameters from each of the studies.
- Reference data for estimation of the joint distribution of all the distinct covariates across studies.

The software provides flexibility to the users to choose the intercepts to be different (when the model is logistic) across studies through the input argument, `variable_intercepts`. It also allows estimation of the regression parameters, only from the sample sizes of the studies when it is difficult to obtain estimate of the variance-covariance matrices.

Note: GENMETA will not work if both the estimates of the covariance matrix and the sample size are NULL.

When the model is "linear", it is assumed that the outcome is standardized to have unit variance. For more details on the IRWLS, see References. If one of the studies has information on all the covariates, then the user can use that study to provide their own estimate for the initial vector. Note that this option is currently available for linear model and logistic model with variable intercepts set to FALSE. In particular, the user can use the `glm` function from stats package in R to fit the maximal model on that study and extract the coefficients from the model fit.

Value

An object of class "GENMETA" is a list containing GENMETA estimate, its variance-covariance matrix and estimates the residual variance in the case of "linear" model .

<code>Est.coeff</code>	a numeric vector containing the estimated regression coefficients of the maximal model using optimal weighting matrix.
------------------------	--

Est.var.cov	a matrix containing estimate of variance-covariance matrix of the corresponding GENMETA estimator.
Res.var	a numeric containing the residual variance of the maximal model when it is linear. It is calculated from the formula : $1 - \hat{\beta}_{GENMETA}^T var(X) \hat{\beta}_{GENMETA}$ which is derived by assuming the outcomes to have unit variance. $var(X)$ is calculated from reference data. Res.var is NA when the model is "logistic".
iter	a numeric containing the number of iterations used in the algorithm
call	the matched call

The function [GENMETA.summary](#) prints a summary of the results obtained from GENMETA.
 The function [GENMETA.plot](#) plots the estimate of the parameter from each of the studies, the summary measure(GENMETA estimate) and their confidence intervals.

Author(s)

Prosenjit Kundu, Runlong Tang and Nilanjan Chatterjee.

References

Tang, R., Kundu, P. and Chatterjee, N. (2017) Generalized Meta-Analysis for Multivariate Regression Models Across Studies with Disparate Covariate Information. [arXiv:1708.03818v1 \[stat.ME\]](#).

See Also

[GENMETA.summary](#), [GENMETA.plot](#).

Examples

```
# This example shows how to create the inputs GENMETA and then implement generalized meta-analysis
#####
### Basic setting #####
#####
d.X = 3 # number of covariates.
mu = matrix(rep(0,d.X), nrow=d.X) # mean vector of the covariates.
r1 = 0.3 # correlation coefficient of the covariates.
r2 = 0.6
r3 = 0.1
Sigma = matrix(
  c(1, r1, r2,
    r1, 1, r3,
    r2, r3, 1),
  nrow=d.X,
  ncol=d.X) # covariance matrix of the covariates.
beta.star = matrix(c(-1.2, log(1.3), log(1.3), log(1.3)),nrow = d.X+1) # beta.star
#beta.star = matrix(c(-1.2, 0.26, 0.26, 0.26),nrow = d.X+1) # beta.star
#beta.star = matrix(c(-3, 1, 2, 3),nrow = d.X+1) # beta.star
n1 = 300 # sample size of the 1st data set.
n2 = 500 # 2nd
n3 = 1000 # 3rd
n = 50
```

```

sim=1
set.seed(sim)
X.rf = MASS::mvrnorm(n = n, mu, Sigma)
X.m1 = MASS::mvrnorm(n = n1, mu, Sigma) # Generate the covariates.
X.m1.1 = cbind(rep(1, n1), X.m1) # Add a column of 1's to X.m1.
p.m1 = 1/(1+exp(-X.m1.1%*%beta.star)) # the vector of probabilities
Y.m1 = rbinom(n1, size=1, p.m1) # the Bernoulli responses
# print(p.m1[1])
# print(mean(Y.m1))
# print(mean(p.m1))
# Generate data set 2. m1 means model 2.
X.m2 = MASS::mvrnorm(n = n2, mu, Sigma)
X.m2.1 = cbind(rep(1, n2), X.m2)
p.m2 = 1/(1+exp(-X.m2.1%*%beta.star))
Y.m2 = rbinom(n2, size=1, p.m2)
X.m3 = MASS::mvrnorm(n = n3, mu, Sigma)
X.m3.1 = cbind(rep(1, n3), X.m3)
p.m3 = 1/(1+exp(-X.m3.1%*%beta.star))
Y.m3 = rbinom(n3, size=1, p.m3)
#####
### Create data sets in the format of data frame.
#####
data.m1 = data.frame(Y=Y.m1, X.m1)
data.m2 = data.frame(Y=Y.m2, X.m2)
data.m3 = data.frame(Y=Y.m3, X.m3)
#####
### Apply logistic regression with reduced models to the data sets
#####
logit.m1 <- glm(Y ~ X1 + X2, data = data.m1, family = "binomial")
# print(logit.m1)
if(logit.m1$converged == FALSE)
{
  print("glm for logit.m1 is not convergent.")
  next
}
logit.m2 <- glm(Y ~ X2 + X3, data = data.m2, family = "binomial")
# print(logit.m2)
if(logit.m2$converged == FALSE)
{
  print("glm for logit.m2 is not convergent.")
  next
}
logit.m3 <- glm(Y ~ X1 + X3, data = data.m3, family = "binomial")
# print(logit.m3)
if(logit.m3$converged == FALSE)
{
  print("glm for logit.m3 is not convergent.")
  next
}
#####
### Obtain the estimators of the parameters in the reduced models.
#####
theta.m1 = logit.m1$coefficients

```

```

theta.m2 = logit.m2$coefficients
theta.m3 = logit.m3$coefficients
#####
### Find the covariance matrix estimators for the reduced models
#####
#####
# Basic notations for inputs
#####
K = 3 # Number of data sets
A1 = c(1, 2) # index set A1, the indexes of the covariates of data set 1.
A2 = c(2, 3) # index set A2
A3 = c(1, 3) # index set A3
X.m1.used = cbind(rep(1, n1), X.m1[, A1, drop=FALSE])
X.m2.used = cbind(rep(1, n2), X.m2[, A2, drop=FALSE])
X.m3.used = cbind(rep(1, n3), X.m3[, A3, drop=FALSE])
# str(X.m1.used)
# str(X.m2.used)
# str(X.m3.used)
##### Find Sigma.m1
T.1 = matrix(rep(0, (length(A1)+1)^2), nrow=length(A1)+1)
T.2 = T.1
for (i in 1:n1)
{
a = as.vector(exp(-X.m1.used[i, , drop=FALSE]**theta.m1))
T.1 = T.1 + (a/(1+a)^2) * (t(X.m1.used[i, , drop=FALSE])**X.m1.used[i, , drop=FALSE])
}
for (i in 1:n1)
{
a = as.vector(1/(1 + exp(-X.m1.used[i, , drop=FALSE]**theta.m1)))
T.2 = T.2 + (Y.m1[i]-a)^2 * (t(X.m1.used[i, , drop=FALSE])**X.m1.used[i, , drop=FALSE])
}
Sigma.m1 = solve(T.1)**T.2**solve(T.1) # This is actually Sigma.m1.n1.
##### Find Sigma.m2
T.1 = matrix(rep(0, (length(A2)+1)^2), nrow=length(A2)+1)
T.2 = T.1
for (i in 1:n2)
{
a = as.vector(exp(-X.m2.used[i, , drop=FALSE]**theta.m2))
T.1 = T.1 + (a/(1+a)^2) * (t(X.m2.used[i, , drop=FALSE])**X.m2.used[i, , drop=FALSE])
}
for (i in 1:n2)
{
a = as.vector(1/(1 + exp(-X.m2.used[i, , drop=FALSE]**theta.m2)))
T.2 = T.2 + (Y.m2[i]-a)^2 * (t(X.m2.used[i, , drop=FALSE])**X.m2.used[i, , drop=FALSE])
}
Sigma.m2 = solve(T.1)**T.2**solve(T.1)
##### Find Sigma.m3
T.1 = matrix(rep(0, (length(A3)+1)^2), nrow=length(A3)+1)
T.2 = T.1
for (i in 1:n3)
{
a = as.vector(exp(-X.m3.used[i, , drop=FALSE]**theta.m3))
T.1 = T.1 + (a/(1+a)^2) * (t(X.m3.used[i, , drop=FALSE])**X.m3.used[i, , drop=FALSE])
}

```

```

}
for (i in 1:n3)
{
  a = as.vector(1/( 1 + exp(-X.m3.used[i, , drop=FALSE]**theta.m3)))
  T.2 = T.2 + (Y.m3[i]-a)^2 * (t(X.m3.used[i, , drop=FALSE])**X.m3.used[i, , drop=FALSE])
}
Sigma.m3 = solve(T.1)**T.2**solve(T.1)
names(theta.m1)=c("Intercept","Age","Height")
names(theta.m2)=c("Intercept","Height", "Weight")
names(theta.m3)=c("Intercept","Age", "Weight")
study1 = list(Coeff=theta.m1,Covariance=NULL,Sample_size=n1)
study2 = list(Coeff=theta.m2,Covariance=NULL,Sample_size=n2)
study3 = list(Coeff=theta.m3,Covariance=NULL,Sample_size=n3)
studies = list(study1,study2,study3)
model = "logistic"
reference = cbind(rep(1,n), X.rf)
colnames(reference) = c("Intercept","Age","Height", "Weight")
same.inter = GENMETA(studies, reference, model, initial_val = c(-1.2, log(1.3), log(1.3), log(1.3)))
diff.inter = GENMETA(studies, reference, model, variable_intercepts=TRUE)

```

GENMETA.control

Auxiliary for controlling the IRWLS algorithm

Description

This is an auxiliary function for the iteratively reweighted least squares algorithm for GENMETA. This is used internally by the `myoptim` function, but can be used by the user to create a control argument in the GENMETA function

Usage

```
GENMETA.control(epsilon = 1e-06, maxit = 1000)
```

Arguments

<code>epsilon</code>	a positive numeric indicating convergence tolerance; the algorithm stops when the absolute difference between the estimates in current and previous step is less than <code>epsilon</code> , i.e. $ estimate_{new} - estimate_{old} < \epsilon$
<code>maxit</code>	a positive number indicating the maximum number of iterations to be used in the algorithm. Default is 1000.

Value

A list with components named as the arguments.

Examples

```
control <- GENMETA.control(1e-08, 100)
```

 GENMETA.plot

Generalized Meta-analysis(forest plot)

Description

This function plots the confidence intervals with boxes as the study specific estimates and diamond as the GENMETA estimate. For the current version, it assumes that the estimate of the variance-covariance matrix in each of the studies is provided. It is demonstrated using a different dataset, "study_info_plot", which meets the assumption.

Usage

```
GENMETA.plot(x, study_info_plot)
```

Arguments

x an object of class "GENMETA"
 study_info_plot a list of lists containing information about the studies(similar to the study_info argument used in GENMETA function.)

Examples

```
# This example shows how to obtain the forest plot of GENMETA object.
#####
### Basic setting #####
#####
d.X = 3 # number of covariates.
mu = matrix(rep(0,d.X), nrow=d.X) # mean vector of the covariates.
r1 = 0.3 # correlation coefficient of the covariates.
r2 = 0.6
r3 = 0.1
Sigma = matrix(
  c(1, r1, r2,
    r1, 1, r3,
    r2, r3, 1),
  nrow=d.X,
  ncol=d.X) # covariance matrix of the covariates.
beta.star = matrix(c(-1.2, log(1.3), log(1.3), log(1.3)),nrow = d.X+1)
#beta.star = matrix(c(-1.2, 0.26, 0.26, 0.26),nrow = d.X+1) # beta.star
#beta.star = matrix(c(-3, 1, 2, 3),nrow = d.X+1) # beta.star
n1 = 300 # sample size of the 1st data set.
n2 = 500 # 2nd
n3 = 1000 # 3rd
n = 50
sim=1
set.seed(sim)
X.rf = MASS::mvrnorm(n = n, mu, Sigma)
X.m1 = MASS::mvrnorm(n = n1, mu, Sigma) # Generate the covariates.
```



```

X.m1.1 = cbind(rep(1, n1), X.m1) # Add a column of 1's to X.m1.
p.m1 = 1/(1+exp(-X.m1.1%*%beta.star)) # the vector of probabilities
Y.m1 = rbinom(n1, size=1, p.m1) # the Bernoulli responses
# print(p.m1[1])
# print(mean(Y.m1))
# print(mean(p.m1))
# Generate data set 2. m1 means model 2.
X.m2 = MASS::mvrnorm(n = n2, mu, Sigma)
X.m2.1 = cbind(rep(1, n2), X.m2)
p.m2 = 1/(1+exp(-X.m2.1%*%beta.star))
Y.m2 = rbinom(n2, size=1, p.m2)
X.m3 = MASS::mvrnorm(n = n3, mu, Sigma)
X.m3.1 = cbind(rep(1, n3), X.m3)
p.m3 = 1/(1+exp(-X.m3.1%*%beta.star))
Y.m3 = rbinom(n3, size=1, p.m3)
#####
### Create data sets in the format of data frame.
#####
data.m1 = data.frame(Y=Y.m1, X.m1)
data.m2 = data.frame(Y=Y.m2, X.m2)
data.m3 = data.frame(Y=Y.m3, X.m3)
#####
### Apply logistic regression with reduced models to the data sets
#####
logit.m1 <- glm(Y ~ X1 + X2, data = data.m1, family = "binomial")
# print(logit.m1)
if(logit.m1$converged == FALSE)
{
  print("glm for logit.m1 is not convergent.")
  next
}
logit.m2 <- glm(Y ~ X2 + X3, data = data.m2, family = "binomial")
# print(logit.m2)
if(logit.m2$converged == FALSE)
{
  print("glm for logit.m2 is not convergent.")
  next
}
logit.m3 <- glm(Y ~ X1 + X3, data = data.m3, family = "binomial")
# print(logit.m3)
if(logit.m3$converged == FALSE)
{
  print("glm for logit.m3 is not convergent.")
  next
}
#####
### Obtain the estimators of the parameters in the reduced models.
#####
theta.m1 = logit.m1$coefficients
theta.m2 = logit.m2$coefficients
theta.m3 = logit.m3$coefficients
#####
### Find the covariance matrix estimators for the reduced models

```

```

#####
#####
# Basic notations for inputs
#####
K = 3 # Number of data sets
A1 = c(1, 2) # index set A1, the indexes of the covariates of data set 1.
A2 = c(2, 3) # index set A2
A3 = c(1, 3) # index set A3
X.m1.used = cbind(rep(1, n1), X.m1[, A1, drop=FALSE])
X.m2.used = cbind(rep(1, n2), X.m2[, A2, drop=FALSE])
X.m3.used = cbind(rep(1, n3), X.m3[, A3, drop=FALSE])
# str(X.m1.used)
# str(X.m2.used)
# str(X.m3.used)
##### Find Sigma.m1
T.1 = matrix(rep(0, (length(A1)+1)^2), nrow=length(A1)+1)
T.2 = T.1
for (i in 1:n1)
{
a = as.vector(exp(-X.m1.used[i, , drop=FALSE]**theta.m1))
T.1 = T.1 + (a/(1+a)^2) * (t(X.m1.used[i, , drop=FALSE])**X.m1.used[i, , drop=FALSE])
}
for (i in 1:n1)
{
a = as.vector(1/(1 + exp(-X.m1.used[i, , drop=FALSE]**theta.m1)))
T.2 = T.2 + (Y.m1[i]-a)^2 * (t(X.m1.used[i, , drop=FALSE])**X.m1.used[i, , drop=FALSE])
}
Sigma.m1 = solve(T.1)**T.2**solve(T.1) # This is actually Sigma.m1.n1.
##### Find Sigma.m2
T.1 = matrix(rep(0, (length(A2)+1)^2), nrow=length(A2)+1)
T.2 = T.1
for (i in 1:n2)
{
a = as.vector(exp(-X.m2.used[i, , drop=FALSE]**theta.m2))
T.1 = T.1 + (a/(1+a)^2) * (t(X.m2.used[i, , drop=FALSE])**X.m2.used[i, , drop=FALSE])
}
for (i in 1:n2)
{
a = as.vector(1/(1 + exp(-X.m2.used[i, , drop=FALSE]**theta.m2)))
T.2 = T.2 + (Y.m2[i]-a)^2 * (t(X.m2.used[i, , drop=FALSE])**X.m2.used[i, , drop=FALSE])
}
Sigma.m2 = solve(T.1)**T.2**solve(T.1)
##### Find Sigma.m3
T.1 = matrix(rep(0, (length(A3)+1)^2), nrow=length(A3)+1)
T.2 = T.1
for (i in 1:n3)
{
a = as.vector(exp(-X.m3.used[i, , drop=FALSE]**theta.m3))
T.1 = T.1 + (a/(1+a)^2) * (t(X.m3.used[i, , drop=FALSE])**X.m3.used[i, , drop=FALSE])
}
for (i in 1:n3)
{
a = as.vector(1/(1 + exp(-X.m3.used[i, , drop=FALSE]**theta.m3)))

```

```

    T.2 = T.2 + (Y.m3[i]-a)^2 * (t(X.m3.used[i, , drop=FALSE])%*%X.m3.used[i, , drop=FALSE])
  }
  Sigma.m3 = solve(T.1)%*%T.2%*%solve(T.1)
  names(theta.m1)=c("Intercept","Age","Height")
  names(theta.m2)=c("Intercept","Height", "Weight")
  names(theta.m3)=c("Intercept","Age", "Weight")
  study1 = list(Coeff=theta.m1,Covariance=Sigma.m1,Sample_size=n1)
  study2 = list(Coeff=theta.m2,Covariance=Sigma.m2,Sample_size=n2)
  study3 = list(Coeff=theta.m3,Covariance=Sigma.m3,Sample_size=n3)
  studies = list(study1,study2,study3)
  model = "logistic"
  reference = cbind(rep(1,n), X.rf)
  colnames(reference) = c("Intercept","Age","Height", "Weight")
  result_diff <- GENMETA(studies, reference, model, variable_intercepts = TRUE)
  GENMETA.plot(result_diff, studies)

```

 GENMETA.summary

Summarizing Generalized Meta Analysis

Description

This function prints the summary of GENMETA results.

Usage

```
GENMETA.summary(object, signi_digits = 3)
```

Arguments

<code>object</code>	an object of class "GENMETA"
<code>signi_digits</code>	an optional numeric indicating the number of significant digits to be shown in the summary. Default is 3.

Examples

```

# This example shows how to obtain the summary of GENMETA object.
#####
### Basic setting
#####
d.X = 3 # number of covariates.
mu = matrix(rep(0,d.X), nrow=d.X) # mean vector of the covariates.
r1 = 0.3 # correlation coefficient of the covariates.
r2 = 0.6
r3 = 0.1
Sigma = matrix(
  c(1, r1, r2,
    r1, 1, r3,
    r2, r3, 1),
  nrow=d.X,

```

```

ncol=d.X) # covariance matrix of the covariates.
beta.star = matrix(c(-1.2, log(1.3), log(1.3), log(1.3)),nrow = d.X+1) # beta.star
#beta.star = matrix(c(-1.2, 0.26, 0.26, 0.26),nrow = d.X+1) # beta.star
#beta.star = matrix(c(-3, 1, 2, 3),nrow = d.X+1) # beta.star
n1 = 300 # sample size of the 1st data set.
n2 = 500 # 2nd
n3 = 1000 # 3rd
n = 50
sim=1
set.seed(sim)
X.rf = MASS::mvrnorm(n = n, mu, Sigma)
X.m1 = MASS::mvrnorm(n = n1, mu, Sigma) # Generate the covariates.
X.m1.1 = cbind(rep(1, n1), X.m1) # Add a column of 1's to X.m1.
p.m1 = 1/(1+exp(-X.m1.1%*%beta.star)) # the vector of probabilities
Y.m1 = rbinom(n1, size=1, p.m1) # the Bernoulli responses
# print(p.m1[1])
# print(mean(Y.m1))
# print(mean(p.m1))
# Generate data set 2. m1 means model 2.
X.m2 = MASS::mvrnorm(n = n2, mu, Sigma)
X.m2.1 = cbind(rep(1, n2), X.m2)
p.m2 = 1/(1+exp(-X.m2.1%*%beta.star))
Y.m2 = rbinom(n2, size=1, p.m2)
X.m3 = MASS::mvrnorm(n = n3, mu, Sigma)
X.m3.1 = cbind(rep(1, n3), X.m3)
p.m3 = 1/(1+exp(-X.m3.1%*%beta.star))
Y.m3 = rbinom(n3, size=1, p.m3)
#####
### Create data sets in the format of data frame.
#####
data.m1 = data.frame(Y=Y.m1, X.m1)
data.m2 = data.frame(Y=Y.m2, X.m2)
data.m3 = data.frame(Y=Y.m3, X.m3)
#####
### Apply logistic regression with reduced models to the data sets
#####
logit.m1 <- glm(Y ~ X1 + X2, data = data.m1, family = "binomial")
# print(logit.m1)
if(logit.m1$converged == FALSE)
{
  print("glm for logit.m1 is not convergent.")
  next
}
logit.m2 <- glm(Y ~ X2 + X3, data = data.m2, family = "binomial")
# print(logit.m2)
if(logit.m2$converged == FALSE)
{
  print("glm for logit.m2 is not convergent.")
  next
}
logit.m3 <- glm(Y ~ X1 + X3, data = data.m3, family = "binomial")
# print(logit.m3)
if(logit.m3$converged == FALSE)

```

```

{
  print("glm for logit.m3 is not convergent.")
  next
}
#####
### Obtain the estimators of the parameters in the reduced models.
#####
theta.m1 = logit.m1$coefficients
theta.m2 = logit.m2$coefficients
theta.m3 = logit.m3$coefficients
#####
### Find the covariance matrix estimators for the reduced models
#####
#####
# Basic notations for inputs
#####
K = 3 # Number of data sets
A1 = c(1, 2) # index set A1, the indexes of the covariates of data set 1.
A2 = c(2, 3) # index set A2
A3 = c(1, 3) # index set A3
X.m1.used = cbind(rep(1, n1), X.m1[, A1, drop=FALSE])
X.m2.used = cbind(rep(1, n2), X.m2[, A2, drop=FALSE])
X.m3.used = cbind(rep(1, n3), X.m3[, A3, drop=FALSE])
# str(X.m1.used)
# str(X.m2.used)
# str(X.m3.used)
##### Find Sigma.m1
T.1 = matrix(rep(0, (length(A1)+1)^2), nrow=length(A1)+1)
T.2 = T.1
for (i in 1:n1)
{
  a = as.vector(exp(-X.m1.used[i, , drop=FALSE]%%theta.m1))
  T.1 = T.1 + (a/(1+a)^2) * (t(X.m1.used[i, , drop=FALSE])%%X.m1.used[i, , drop=FALSE])
}
for (i in 1:n1)
{
  a = as.vector(1/( 1 + exp(-X.m1.used[i, , drop=FALSE]%%theta.m1)))
  T.2 = T.2 + (Y.m1[i]-a)^2 * (t(X.m1.used[i, , drop=FALSE])%%X.m1.used[i, , drop=FALSE])
}
Sigma.m1 = solve(T.1)%%T.2%%solve(T.1) # This is actually Sigma.m1.n1.
##### Find Sigma.m2
T.1 = matrix(rep(0, (length(A2)+1)^2), nrow=length(A2)+1)
T.2 = T.1
for (i in 1:n2)
{
  a = as.vector(exp(-X.m2.used[i, , drop=FALSE]%%theta.m2))
  T.1 = T.1 + (a/(1+a)^2) * (t(X.m2.used[i, , drop=FALSE])%%X.m2.used[i, , drop=FALSE])
}
for (i in 1:n2)
{
  a = as.vector(1/( 1 + exp(-X.m2.used[i, , drop=FALSE]%%theta.m2)))
  T.2 = T.2 + (Y.m2[i]-a)^2 * (t(X.m2.used[i, , drop=FALSE])%%X.m2.used[i, , drop=FALSE])
}

```

```

Sigma.m2 = solve(T.1)%*%T.2*solve(T.1)
#### Find Sigma.m3
T.1 = matrix(rep(0, (length(A3)+1)^2), nrow=length(A3)+1)
T.2 = T.1
for (i in 1:n3)
{
  a = as.vector(exp(-X.m3.used[i, , drop=FALSE]*%*%theta.m3))
  T.1 = T.1 + (a/(1+a)^2) * (t(X.m3.used[i, , drop=FALSE])%*%X.m3.used[i, , drop=FALSE])
}
for (i in 1:n3)
{
  a = as.vector(1/( 1 + exp(-X.m3.used[i, , drop=FALSE]*%*%theta.m3)))
  T.2 = T.2 + (Y.m3[i]-a)^2 * (t(X.m3.used[i, , drop=FALSE])%*%X.m3.used[i, , drop=FALSE])
}
Sigma.m3 = solve(T.1)%*%T.2*solve(T.1)
names(theta.m1)=c("Intercept","Age","Height")
names(theta.m2)=c("Intercept","Height", "Weight")
names(theta.m3)=c("Intercept","Age", "Weight")
study1 = list(Coeff=theta.m1,Covariance=Sigma.m1,Sample_size=n1)
study2 = list(Coeff=theta.m2,Covariance=Sigma.m2,Sample_size=n2)
study3 = list(Coeff=theta.m3,Covariance=Sigma.m3,Sample_size=n3)
studies = list(study1,study2,study3)
model = "logistic"
reference = cbind(rep(1,n), X.rf)
colnames(reference) = c("Intercept","Age","Height", "Weight")
result.same = GENMETA(studies, reference, model,
initial_val = c(-1.2, log(1.3), log(1.3), log(1.3)))
GENMETA.summary(result.same)

```

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