Package 'GxEprs'

August 17, 2023

Title Genotype-by-Environment Interaction in Polygenic Score Models	
Version 1.0	

Description A novel PRS model is introduced to enhance the prediction accuracy by utilising GxE effects. This package performs Genome Wide Association Studies (GWAS) and Genome Wide Environment Interaction Studies (GWEIS) using a discovery dataset. The package has the ability to obtain polygenic risk scores (PRSs) for a target sample. Finally it predicts the risk values of each individual in the target sample. Users have the choice of using existing models (Li et al., 2015) <doi:10.1093/annonc/mdu565>, (Pandis et al., 2013) <doi:10.1093/ejo/cjt054>, (Peyrot et al., 2018) <doi:10.1016/j.biopsych.2017.09.009> and (Song et al., 2022) <doi:10.1038/s41467-022-32407-9>, as well as newly proposed models for genomic risk prediction (refer to the URL for more details).

URL https://github.com/DoviniJ/GxEprs

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Description

Covariate data file of the discovery dataset when the outcome is binary This contains covariate information of the individuals in the discovery dataset following confounders

Usage

Bcov_discovery

Format

A dataframe with 800 rows and 18 columns

Column 1 Family ID

Column 2 Individual ID

Column 3 Standardized covariate

Column 4 Square of the standardized covariate

Column 5 Confounder 1

Column 6 Confounder 2

Column 7 Confounder 3

Column 8 Confounder 4

Column 9 Confounder 5

Column 10 Confounder 6

Column 11 Confounder 7

Column 12 Confounder 8

Column 13 Confounder 9

Column 14 Confounder 10

Column 15 Confounder 11

Column 16 Confounder 12

Column 17 Confounder 13

Column 17 Comounder 13

Column 18 Confounder 14

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Bcov_target	Covariate data file of the target dataset when the outcome is binary This contains covariate information of the individuals in the target dataset following confounders

Description

Covariate data file of the target dataset when the outcome is binary This contains covariate information of the individuals in the target dataset following confounders

Usage

```
Bcov_target
```

Format

A dataframe with 200 rows and 18 columns

Column 1 Family ID

Column 2 Individual ID

Column 3 Standardized covariate

Column 4 Square of the standardized covariate

Column 5 Confounder 1

Column 6 Confounder 2

Column 7 Confounder 3

Column 8 Confounder 4

Column 9 Confounder 5

Column 10 Confounder 6

Column 11 Confounder 7

Column 12 Confounder 8

Column 13 Confounder 9

Column 14 Confounder 10

Column 15 Confounder 11

Column 16 Confounder 12

Column 17 Confounder 13

Column 18 Confounder 14

Bphe_target

Bphe_discovery	Phenotype data file of the discovery dataset when the outcome is bi-
	nary This contains phenotype information of the individuals in the dis-
	covery dataset

Description

Phenotype data file of the discovery dataset when the outcome is binary This contains phenotype information of the individuals in the discovery dataset

Usage

```
Bphe_discovery
```

Format

A dataframe with 800 rows and 3 columns

Column 1 Family ID

Column 2 Individual ID

Column 3 Phenotype (1=controls, 2=cases)

Bphe_target Phenotype data file of the target dataset when the outcome is binary
This contains phenotype information of the individuals in the target
dataset

Description

Phenotype data file of the target dataset when the outcome is binary This contains phenotype information of the individuals in the target dataset

Usage

```
Bphe_target
```

Format

A dataframe with 200 rows and 3 columns

Column 1 Family ID

Column 2 Individual ID

Column 3 Phenotype (0=controls, 1=cases)

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DummyData.bim

PLINK .bim file

Description

PLINK .bim file

Usage

DummyData.bim

Format

This follows PLINK general format

Column 1 Chromosome ID

Column 2 SNP ID

Column 3 Position of centimorgans

Column 4 Base-pair coordinate

Column 5 Minor Allele

Column 6 Reference Allele

DummyData.fam

PLINK .fam file

Description

PLINK .fam file

Usage

DummyData.fam

Format

This follows PLINK general format

Column 1 Family ID

Column 2 Individual ID

Column 3 Father's ID

Column 4 Mother's ID

Column 5 Sex

Column 6 Phenotype value

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DummyData.map

PLINK .map file

Description

PLINK .map file

Usage

DummyData.map

Format

This follows PLINK general format

DummyData.ped

PLINK .ped file

Description

PLINK .ped file

Usage

DummyData.ped

Format

This follows PLINK general format

GWAS_binary

GWAS_binary function This function performs GWAS using plink2 and outputs the GWAS summary statistics with additive SNP effects. Users may save the output in a user-specified file (see example).

Description

GWAS_binary function This function performs GWAS using plink2 and outputs the GWAS summary statistics with additive SNP effects. Users may save the output in a user-specified file (see example).

Usage

```
GWAS_binary(plink_path, b_file, Bphe_discovery, Bcov_discovery, thread = 20)
```

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Arguments

plink_path Path to the PLINK executable application

b_file Prefix of the binary files, where all .fam, .bed and .bim files have a common

prefix

Bphe_discovery

Name (with file extension) of the phenotype file containing family ID, individual ID and phenotype of the discovery dataset as columns, without heading

Bcov_discovery

Name (with file extension) of the covariate file containing family ID, individual ID, standardized covariate, square of standardized covariate, and/or confounders

of the discovery dataset as columns, without heading

thread Number of threads used

Value

This function will perform GWAS and output

```
B_out.trd.sum
```

GWAS summary statistics with additive SNP effects

Examples

```
## Not run:
x <- GWAS_binary(plink_path, DummyData, Bphe_discovery, Bcov_discovery,
thread = 20)
sink("B_out.trd.sum") #to create a file in the working directory
write.table(x[c("ID", "A1", "OR")], sep = " ",
row.names = FALSE, quote = FALSE) #to write the output
sink() #to save the output
head(x) #to obtain the head of GWAS summary statistics of additive SNP effects
x$CHROM #to extract the chromosome number
x$POS #to extract the base pair position
x$ID #to extract the SNP ID
x$REF #to extract the reference allele
x$ALT #to extract the alternate allele
x$A1 $\#to extract the minor allele
x$OBS_CT #to extract the number of allele observations
x$OR $\#to extract the odds ratios of the SNP effects
x$LOG_OR_SE #to extract the standard errors of log odds
x$Z\_STAT #to extract the test statistics
x$P #to extract the p values
## End(Not run)
```

GWAS_quantitative

GWAS_quantitative function This function performs GWAS using plink2 and outputs the GWAS summary statistics with additive SNP effects. Users may save the output in a user-specified file (see example).

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Description

GWAS_quantitative function This function performs GWAS using plink2 and outputs the GWAS summary statistics with additive SNP effects. Users may save the output in a user-specified file (see example).

Usage

```
GWAS_quantitative(
  plink_path,
  b_file,
  Qphe_discovery,
  Qcov_discovery,
  thread = 20
)
```

Arguments

plink_path Path to the PLINK executable application

b_file Prefix of the binary files, where all .fam, .bed and .bim files have a common prefix

pre

Qphe_discovery

Name (with file extension) of the phenotype file containing family ID, individual

ID and phenotype of the discovery dataset as columns, without heading

Qcov discovery

Name (with file extension) of the covariate file containing family ID, individual ID, standardized covariate, square of standardized covariate, and/or confounders of the discovery dataset as columns, without heading

thread Number of threads used

Value

This function will perform GWAS and output

```
Q_out.trd.sum
```

GWAS summary statistics with additive SNP effects

```
## Not run:
x <- GWAS_quantitative(plink_path, DummyData, Qphe_discovery, Qcov_discovery,
thread = 20)
sink("Q_out.trd.sum") #to create a file in the working directory
write.table(x[c("ID", "A1", "BETA")], sep = " ",
row.names = FALSE, quote = FALSE) #to write the output
sink() #to save the output
head(x) #to obtain the head of GWAS summary statistics of additive SNP effects
x$CHROM #to extract the chromosome number
x$POS #to extract the base pair position
x$ID #to extract the SNP ID
x$REF #to extract the reference allele
x$ALT #to extract the alternate allele
x$A1 #to extract the minor allele
x$OBS_CT #to extract the number of allele observations
x\$BETA #to extract the SNP effects
```

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```
x$SE #to extract the standard errors of the SNP effects
x$T_STAT #to extract the test statistics
x$P #to extract the p values
## End(Not run)
```

GWEIS_binary

GWEIS_binary function This function performs GWEIS using plink2 and outputs the GWEIS summary statistics with additive SNP effects and interaction SNP effects. Users may save the outputs in separate user-specified files (see examples).

Description

GWEIS_binary function This function performs GWEIS using plink2 and outputs the GWEIS summary statistics with additive SNP effects and interaction SNP effects. Users may save the outputs in separate user-specified files (see examples).

Usage

```
GWEIS_binary(plink_path, b_file, Bphe_discovery, Bcov_discovery, thread = 20)
```

Arguments

Path to the PLINK executable application plink_path b file Prefix of the binary files, where all .fam, .bed and .bim files have a common prefix Bphe_discovery Phenotype file containing family ID, individual ID and phenotype of the discovery dataset as columns, without heading Bcov_discovery Covariate file containing family ID, individual ID, standardized covariate, square

of standardized covariate, and/or confounders of the discovery dataset as columns, without heading

thread Number of threads used

Value

This function will perform GWEIS and output

B_out.sum GWEIS summary statistics with additive and interaction SNP effects

```
## Not run:
x <- GWEIS_binary(plink_path, DummyData, Bphe_discovery, Bcov_discovery,
thread = 20)
sink("B_out.add.sum") #to create a file in the working directory
write.table(x[c("ID", "A1", "ADD_OR")], sep = " ",
row.names = FALSE, quote = FALSE) #to write the output
sink() #to save the output
sink("B_out.gxe.sum") #to create a file in the working directory
```

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```
write.table(x[c("ID", "A1", "INTERACTION_OR")], sep = " ",
row.names = FALSE, quote = FALSE) #to write the output
sink() #to save the output
head(x) #to extract the head of all columns in GWEIS summary statistics of
additive and interaction SNP effects
x$CHROM #to extract the chromosome number
x$POS #to extract the base pair position
x$ID #to extract the SNP ID
x$REF #to extract the reference allele
x$ALT #to extract the alternate allele
x$A1 #to extract the minor allele
x$OBS_CT #to extract the number of allele observations
x$ADD_OR #to extract the odds ratios of additive SNP effects
x$ADD_LOG_OR_SE #to extract the standard errors of log odds of
additive SNP effects
x$ADD_Z\_STAT #to extract the test statistics of additive SNP effects
x$ADD_P #to extract the p values of additive SNP effects
x$INTERACTION_OR #to extract the odds ratios of the SNP effects of
interaction SNP effects
x$INTERACTION\_LOG\_OR\_SE #to extract the standard errors of log odds
of interaction SNP effects
x$INTERACTION_Z_STAT #to extract the test statistics of interaction
SNP effects
x$INTERACTION_P #to extract the p values of interaction SNP effects
## End(Not run)
```

GWEIS_quantitative GWEIS_quantitative function This function performs GWEIS using plink2 and outputs the GWEIS summary statistics with additive SNP effects and interaction SNP effects separately. It is recommended to save the outputs in separate user-specified files (see examples).

Description

GWEIS_quantitative function This function performs GWEIS using plink2 and outputs the GWEIS summary statistics with additive SNP effects and interaction SNP effects separately. It is recommended to save the outputs in separate user-specified files (see examples).

Usage

```
GWEIS_quantitative(
   plink_path,
   b_file,
   Qphe_discovery,
   Qcov_discovery,
   thread = 20
)
```

Arguments

plink_path Path to the PLINK executable application

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b_file Prefix of the binary files, where all .fam, .bed and .bim files have a common prefix

Qphe_discovery

Phenotype file containing family ID, individual ID and phenotype of the discovery dataset as columns, without heading

Qcov_discovery

Covariate file containing family ID, individual ID, standardized covariate, square of standardized covariate, and/or confounders of the discovery dataset as columns, without heading

thread Number of threads used

Value

This function will perform GWEIS and output

Q_out.sum GWEIS summary statistics with additive and interaction SNP effects

```
x <- GWEIS_quantitative (plink_path, DummyData, Qphe_discovery, Qcov_discovery,
thread = 20)
sink("Q_out.add.sum") #to create a file in the working directory
write.table(x[c("ID", "A1", "ADD_BETA")], sep = " ",
row.names = FALSE, quote = FALSE) #to write the output
sink() #to save the output
sink("Q_out.gxe.sum") #to create a file in the working directory
write.table(x[c("ID", "A1", "INTERACTION_BETA")], sep = " ",
row.names = FALSE, quote = FALSE) #to write the output
sink() #to save the output
head(x) #to extract the head of all columns in GWEIS summary statistics of
additive and interaction SNP effects
x$CHROM #to extract the chromosome number
x$POS #to extract the base pair position
x$ID #to extract the SNP ID
xREF #to extract the reference allele
x$ALT #to extract the alternate allele
x$A1 #to extract the minor allele
x$OBS_CT #to extract the number of allele observations
x$ADD_BETA #to extract the additive SNP effects
x$ADD_SE #to extract the standard errors of the
additive SNP effects
x$ADD_T_STAT #to extract the test statistics of additive
SNP effects
x$ADD_P #to extract the p values of additive SNP effects
x$INTERACTION_BETA #to extract the interaction SNP effects
x\$INTERACTION\_SE #to extract the standard errors of the
interaction SNP effects
x$INTERACTION T STAT #to extract the test statistics of
interaction SNP effects
x$INTERACTION_P #to extract the p values of interaction
SNP effects
## End(Not run)
```

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PRS_binary

PRS_binary function This function uses plink2 and outputs Polygenic Risk Scores (PRSs) of all the individuals, using pre-generated GWAS and/or GWEIS summary statistics. Note that the input used in this function can be generated by using GWAS_binary and/or GWEIS_binary functions. Users may save the output in a user-specified file (see examples).

Description

PRS_binary function This function uses plink2 and outputs Polygenic Risk Scores (PRSs) of all the individuals, using pre-generated GWAS and/or GWEIS summary statistics. Note that the input used in this function can be generated by using GWAS_binary and/or GWEIS_binary functions. Users may save the output in a user-specified file (see examples).

Usage

```
PRS_binary(plink_path, b_file, summary_input)
```

Arguments

plink_path Path to the PLINK executable application

b_file Prefix of the binary files, where all .fam, .bed and .bim files have a common prefix

summary_input

Pre-generated GWAS and/or GWEIS summary statistics

Value

This function will output

```
prs.sscore PRSs for each individual
```

```
## Not run:
a <- GWAS_binary(plink_path, DummyData, Bphe_discovery, Bcov_discovery)
trd <- a[c("ID", "A1", "OR")]</pre>
b <- GWEIS_binary(plink_path, DummyData, Bphe_discovery, Bcov_discovery)
add <- b[c("ID", "A1", "ADD_OR")]
gxe <- b[c("ID", "A1", "INTERACTION_OR")]</pre>
x <- PRS_binary(plink_path, DummyData, summary_input = trd)</pre>
sink("B_trd.sscore") #to create a file in the working directory
write.table(x, sep = " ", row.names = FALSE, quote = FALSE) #to write the output
sink() #to save the output
head(x) #to read the head of all columns in the output
x\$FID #to extract the family ID's of full dataset
x$IID #to extract the individual ID's of full dataset
x$PRS #to extract the polygenic risk scores of full dataset
y <- PRS_binary(plink_path, DummyData, summary_input = add)
sink("B_add.sscore") #to create a file in the working directory
write.table(y, sep = " ", row.names = FALSE, quote = FALSE) #to write the output
sink() #to save the output
```

PRS_quantitative 13

```
z <- PRS_binary(plink_path, DummyData, summary_input = gxe)
sink("B_gxe.sscore") #to create a file in the working directory
write.table(z, sep = " ", row.names = FALSE, quote = FALSE) #to write the output
sink() #to save the output
## End(Not run)</pre>
```

PRS_quantitative

PRS_quantitative function This function uses plink2 and outputs Polygenic Risk Scores (PRSs) of all the individuals, using pre-generated GWAS and/or GWEIS summary statistics. Note that the input used in this function can be generated by using GWAS_quantitative and/or GWEIS_quantitative functions. Users may save the output in a user-specified file (see examples).

Description

PRS_quantitative function This function uses plink2 and outputs Polygenic Risk Scores (PRSs) of all the individuals, using pre-generated GWAS and/or GWEIS summary statistics. Note that the input used in this function can be generated by using GWAS_quantitative and/or GWEIS_quantitative functions. Users may save the output in a user-specified file (see examples).

Usage

```
PRS_quantitative(plink_path, b_file, summary_input)
```

Arguments

```
plink_path Path to the PLINK executable application

b_file Prefix of the binary files, where all .fam, .bed and .bim files have a common prefix

summary_input
```

Pre-generated GWAS and/or GWEIS summary statistics

Value

This function will output

```
prs.sscore PRSs for each individual
```

```
## Not run:
a <- GWAS_quantitative(plink_path, DummyData, Qphe_discovery, Qcov_discovery)
trd <- a[c("ID", "A1", "BETA")]
b <- GWEIS_quantitative(plink_path, DummyData, Qphe_discovery, Qcov_discovery)
add <- b[c("ID", "A1", "ADD_BETA")]
gxe <- b[c("ID", "A1", "INTERACTION_BETA")]
x <- PRS_quantitative(plink_path, DummyData, summary_input = trd)
sink("Q_trd.sscore") #to create a file in the working directory
write.table(x, sep = " ", row.names = FALSE, quote = FALSE) #to write the output
sink() #to save the output
head(x) #to read the head of all columns in the output</pre>
```

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```
x$FID #to extract the family ID's of full dataset
 x$IID #to extract the individual ID's of full dataset
 x$PRS #to extract the polygenic risk scores of full dataset
 y <- PRS_quantitative(plink_path, DummyData, summary_input = add)
 sink("Q_add.sscore") #to create a file in the working directory
 write.table(y, sep = " ", row.names = FALSE, quote = FALSE) #to write the output
 sink() #to save the output
 z <- PRS_quantitative(plink_path, DummyData, summary_input = gxe)</pre>
 sink("Q_gxe.sscore") #to create a file in the working directory
 write.table(z, sep = " ", row.names = FALSE, quote = FALSE) #to write the output
 sink() #to save the output
 ## End(Not run)
Qcov_discovery
                      Covariate data file of the discovery dataset when the outcome is quan-
                      titative This contains covariate information of the individuals in the
                      discovery dataset following confounders
```

Description

Covariate data file of the discovery dataset when the outcome is quantitative This contains covariate information of the individuals in the discovery dataset following confounders

Usage

Qcov_discovery

Format

A dataframe with 800 rows and 18 columns

Column 1 Family ID

Column 2 Individual ID

Column 3 Standardized covariate

Column 4 Square of the standardized covariate

Column 5 Confounder 1

Column 6 Confounder 2

Column 7 Confounder 3

Column 8 Confounder 4

Column 9 Confounder 5

Column 10 Confounder 6

Column 11 Confounder 7

Column 12 Confounder 8

Column 13 Confounder 9

Column 14 Confounder 10

Column 15 Confounder 11

Column 16 Confounder 12

Column 17 Confounder 13

Column 18 Confounder 14

Qcov_target 15

Qcov_target	Covariate data file of the target dataset when the outcome is quantita-
	tive This contains covariate information of the individuals in the target
	dataset following confounders

Description

Covariate data file of the target dataset when the outcome is quantitative This contains covariate information of the individuals in the target dataset following confounders

Usage

```
Qcov_target
```

Format

A dataframe with 200 rows and 18 columns

Column 1 Family ID

Column 2 Individual ID

Column 3 Standardized covariate

Column 4 Square of the standardized covariate

Column 5 Confounder 1

Column 6 Confounder 2

Column 7 Confounder 3

Column 8 Confounder 4

Column 9 Confounder 5

Column 10 Confounder 6

Column 11 Confounder 7

Column 12 Confounder 8

Column 13 Confounder 9

Column 14 Confounder 10

Column 15 Confounder 11

Column 16 Confounder 12

Column 17 Confounder 13

Column 18 Confounder 14

16 Qphe_target

Qphe_discovery	Phenotype data file of the discovery dataset when the outcome is quantitative This contains phenotype information of the individuals in the
	discovery dataset

Description

Phenotype data file of the discovery dataset when the outcome is quantitative This contains phenotype information of the individuals in the discovery dataset

Usage

```
Qphe_discovery
```

Format

A dataframe with 800 rows and 3 columns

Column 1 Family IDColumn 2 Individual IDColumn 3 Phenotype

Qphe_target

Phenotype data file of the target dataset when the outcome is quantitative This contains phenotype information of the individuals in the target dataset

Description

Phenotype data file of the target dataset when the outcome is quantitative This contains phenotype information of the individuals in the target dataset

Usage

```
Qphe_target
```

Format

A dataframe with 200 rows and 3 columns

Column 1 Family IDColumn 2 Individual IDColumn 3 Phenotype

```
summary_permuted_binary
```

summary_permuted_binary function This function outputs the p value of permuted model in the target dataset, using pre-generated Polygenic Risk Scores (PRSs) of all the individuals. Note that the input used in this function can be generated by using PRS_quantitative function. It is recommended to run this function, if you choose to fit 'PRS_gxe x E' interaction component (i.e. novel proposed model, Model 5) when generating risk scores. If the 'PRS_gxe x E' term is significant in Model 5, and insignificant in Model 5* (permuted p value), consider that the 'PRS_gxe x E' interaction component is actually insignificant (always give priority to the p value obtained from the permuted model).

Description

summary_permuted_binary function This function outputs the p value of permuted model in the target dataset, using pre-generated Polygenic Risk Scores (PRSs) of all the individuals. Note that the input used in this function can be generated by using PRS_quantitative function. It is recommended to run this function, if you choose to fit 'PRS_gxe x E' interaction component (i.e. novel proposed model, Model 5) when generating risk scores. If the 'PRS_gxe x E' term is significant in Model 5, and insignificant in Model 5* (permuted p value), consider that the 'PRS_gxe x E' interaction component is actually insignificant (always give priority to the p value obtained from the permuted model).

Usage

```
summary_permuted_binary(
   Bphe_target,
   Bcov_target,
   iterations = 1000,
   add_score,
   gxe_score
)
```

Arguments

Bphe_target	Phenotype file containing family ID, individual ID and phenotype of the target dataset as columns, without heading
Bcov_target	Covariate file containing family ID, individual ID, standardized covariate, square of standardized covariate, and/or confounders of the target dataset as columns, without heading
iterations	Number of iterations used in permutation
add_score	PRSs generated using additive SNP effects of GWEIS summary statistics
gxe_score	PRSs generated using interaction SNP effects of GWEIS summary statistics

Value

This function will output

B_permuted_p the p value of the permuted model

Examples

```
## Not run:
a <- GWEIS_binary(plink_path, DummyData, Bphe_discovery, Bcov_discovery)
add <- a[c("ID", "A1", "ADD_OR")]
gxe <- a[c("ID", "A1", "INTERACTION_OR")]
p <- PRS_binary(plink_path, DummyData, summary_input = add)
q <- PRS_binary(plink_path, DummyData, summary_input = gxe)
x <- summary_permuted_binary(Bphe_target, Bcov_target, iterations = 1000, add_score = p, gxe_score = q)
x
## End(Not run)</pre>
```

summary_permuted_quantitative

summary_permuted_quantitative function This function outputs the p value of permuted model in the target dataset, using pre-generated Polygenic Risk Scores (PRSs) of all the individuals. Note that the input used in this function can be generated by using PRS_quantitative functions. It is recommended to run this function, if you choose to fit 'PRS_gxe x E' interaction component (i.e. novel proposed model, Model 4) when generating risk scores. If the 'PRS_gxe x E' term is significant in Model 4, and insignificant in Model 4* (permuted p value), consider that the 'PRS_gxe x E' interaction component is actually insignificant (always give priority to the p value obtained from the permuted model).

Description

summary_permuted_quantitative function This function outputs the p value of permuted model in the target dataset, using pre-generated Polygenic Risk Scores (PRSs) of all the individuals. Note that the input used in this function can be generated by using PRS_quantitative functions. It is recommended to run this function, if you choose to fit 'PRS_gxe x E' interaction component (i.e. novel proposed model, Model 4) when generating risk scores. If the 'PRS_gxe x E' term is significant in Model 4, and insignificant in Model 4* (permuted p value), consider that the 'PRS_gxe x E' interaction component is actually insignificant (always give priority to the p value obtained from the permuted model).

Usage

```
summary_permuted_quantitative(
    Qphe_target,
    Qcov_target,
    iterations = 1000,
    add_score,
    gxe_score
)
```

Arguments

Qphe_target Phenotype file containing family ID, individual ID and phenotype of the target dataset as columns, without heading

Qcov_target	Covariate file containing family ID, individual ID, standardized covariate, square of standardized covariate, and/or confounders of the target dataset as columns, without heading
iterations	Number of iterations used in permutation
add_score	PRSs generated using additive SNP effects of GWEIS summary statistics
gxe_score	PRSs generated using interaction SNP effects of GWEIS summary statistics

Value

This function will output

```
Q_permuted_p.txt
```

the p value of the permuted model

Examples

```
## Not run:
a <- GWEIS_quantitative(plink_path, DummyData, Qphe_discovery, Qcov_discovery)
add <- a[c("ID", "A1", "ADD_BETA")]
gxe <- a[c("ID", "A1", "INTERACTION_BETA")]
p <- PRS_quantitative(plink_path, DummyData, summary_input = add)
q <- PRS_quantitative(plink_path, DummyData, summary_input = gxe)
x <- summary_permuted_quantitative(Qphe_target, Qcov_target, iterations = 1000, add_score = p, gxe_score = q)
x
## End(Not run)</pre>
```

```
summary_regular_binary
```

summary_regular_binary function This function outputs the summary of regular model and final risk score values of each individual in the target dataset using pre-generated Polygenic Risk Scores (PRSs) of all the individuals. Note that the input used in this function can be generated by using PRS_binary function.

Description

summary_regular_binary function This function outputs the summary of regular model and final risk score values of each individual in the target dataset using pre-generated Polygenic Risk Scores (PRSs) of all the individuals. Note that the input used in this function can be generated by using PRS_binary function.

Usage

```
summary_regular_binary(
   Bphe_target,
   Bcov_target,
   add_score = NULL,
   gxe_score = NULL,
   Model
)
```

Arguments

Bphe_target Phenotype file containing family ID, individual ID and phenotype of the target dataset as columns, without heading Covariate file containing family ID, individual ID, standardized covariate, square Bcov_target of standardized covariate, and/or confounders of the target dataset as columns, without heading PRSs generated using additive SNP effects of GWAS/GWEIS summary statisadd score tics PRSs generated using interaction SNP effects of GWEIS summary statistics gxe_score Model Specify the model number (0: y = PRS trd + E + confounders, 1: y = PRS trd+ E + PRS_trd x E + confounders, 2: y = PRS_add + E + PRS_add x E + confounders, 3: y = PRS_add + E + PRS_gxe x E + confounders, 4: y = PRS_add $+ E + PRS_gxe + PRS_gxe \times E + confounders$, 5: $y = PRS_add + E + E^2 + E^3$ PRS gxe + PRS gxe x E + confounders, where y is the outcome variable, E is the covariate of interest, PRS_trd and PRS_add are the polygenic risk scores computed using additive SNP effects of GWAS and GWEIS summary statistics respectively, and PRS_gxe is the polygenic risk scores computed using GxE interaction SNP effects of GWEIS summary statistics.)

Value

This function will output

```
Bsummary the summary of the fitted model Individual_risk_values
```

the estimated risk values of individuals in the target sample

```
## Not run:
a <- GWAS_binary(plink_path, DummyData, Bphe_discovery, Bcov_discovery)</pre>
trd <- a[c("ID", "A1", "OR")]</pre>
b <- GWEIS_binary(plink_path, DummyData, Bphe_discovery, Bcov_discovery)
add <- b[c("ID", "A1", "ADD_OR")]
gxe <- b[c("ID", "A1", "INTERACTION_OR")]</pre>
p <- PRS_binary(plink_path, DummyData, summary_input = trd)</pre>
q <- PRS_binary(plink_path, DummyData, summary_input = add)</pre>
r <- PRS_binary(plink_path, DummyData, summary_input = gxe)</pre>
summary_regular_binary(Bphe_target, Bcov_target,
                              add_score = p,
                              Model = 0)
summary_regular_binary(Bphe_target, Bcov_target,
                              add_score = p,
                              Model = 1)
summary_regular_binary(Bphe_target, Bcov_target,
                              add\_score = q,
                              Model = 2)
summary_regular_binary(Bphe_target, Bcov_target,
                              add\_score = q,
                              qxe\_score = r,
                              Model = 3)
summary_regular_binary(Bphe_target, Bcov_target,
                              add\_score = q,
```

```
qxe\_score = r,
                            Model = 4)
x <- summary_regular_binary(Bphe_target, Bcov_target,
                            add_score = q_i
                            qxe\_score = r,
                            Model = 5)
sink("Bsummary.txt") #to create a file in the working directory
print(x$summary) #to write the output
sink() #to save the output
sink("Individual risk values.txt") #to create a file in the working directory
write.table(x$risk.values, sep = " ", row.names = FALSE, col.names = FALSE,
quote = FALSE) #to write the output
sink() #to save the output
x$summary #to obtain the model summary output
x$risk.values #to obtain the predicted risk values of target individuals
## End(Not run)
```

summary_regular_quantitative

summary_regular_quantitative function This function outputs the summary of regular model and final risk score values of each individual in the target dataset using pre-generated Polygenic Risk Scores (PRSs) of all the individuals. Note that the input used in this function can be generated by using PRS_quantitative function.

Description

summary_regular_quantitative function This function outputs the summary of regular model and final risk score values of each individual in the target dataset using pre-generated Polygenic Risk Scores (PRSs) of all the individuals. Note that the input used in this function can be generated by using PRS_quantitative function.

Usage

```
summary_regular_quantitative(
    Qphe_target,
    Qcov_target,
    add_score = NULL,
    gxe_score = NULL,
    Model
)
```

Arguments

Ophe_target Phenotype file containing family ID, individual ID and phenotype of the target dataset as columns, without heading

Ocov_target Covariate file containing family ID, individual ID, standardized covariate, square of standardized covariate, and/or confounders of the target dataset as columns, without heading

Ocov_target PRSs generated using additive SNP effects of GWAS/GWEIS summary statistics.

gxe_score

PRSs generated using interaction SNP effects of GWEIS summary statistics

Model

Specify the model number (0: y = PRS_trd + E + confounders, 1: y = PRS_trd + E + PRS_trd x E + confounders, 2: y = PRS_add + E + PRS_add x E + confounders, 3: y = PRS_add + E + PRS_gxe x E + confounders, 4: y = PRS_add + E + PRS_gxe + PRS_gxe x E + confounders, where y is the outcome variable, E is the covariate of interest, PRS_trd and PRS_add are the polygenic risk scores computed using additive SNP effects of GWAS and GWEIS summary statistics respectively, and PRS_gxe is the polygenic risk scores computed using GxE interaction SNP effects of GWEIS summary statistics.)

Value

This function will output

```
Qsummary.txt the summary of the fitted model Individual_risk_values.txt
```

the estimated risk values of individuals in the target sample

```
## Not run:
a <- GWAS_quantitative(plink_path, DummyData, Qphe_discovery, Qcov_discovery)
trd <- a[c("ID", "A1", "BETA")]</pre>
b <- GWEIS_quantitative(plink_path, DummyData, Qphe_discovery, Qcov_discovery)
add <- b[c("ID", "A1", "ADD_BETA")]
gxe <- b[c("ID", "A1", "INTERACTION_BETA")]</pre>
p <- PRS_quantitative(plink_path, DummyData, summary_input = trd)</pre>
q <- PRS_quantitative(plink_path, DummyData, summary_input = add)</pre>
r <- PRS_quantitative(plink_path, DummyData, summary_input = gxe)</pre>
summary_regular_quantitative(Qphe_target, Qcov_target,
                             add_score = p,
                             Model = 0)
summary_regular_quantitative(Qphe_target, Qcov_target,
                             add_score = p,
                             Model = 1)
summary_regular_quantitative(Qphe_target, Qcov_target,
                             add\_score = q,
                             Model = 2)
summary_regular_quantitative(Qphe_target, Qcov_target,
                             add\_score = q,
                             gxe\_score = r,
                             Model = 3)
x <- summary_regular_quantitative(Qphe_target, Qcov_target,
                             add\_score = q,
                             gxe\_score = r,
                             Model = 4)
sink("Qsummary.txt") #to create a file in the working directory
print(x$summary) #to write the output
sink() #to save the output
sink("Individual_risk_values.txt") #to create a file in the working directory
write.table(x$risk.values, sep = " ", row.names = FALSE, col.names = FALSE,
quote = FALSE) #to write the output
sink() #to save the output
x$summary #to obtain the model summary output
x$risk.values #to obtain the predicted risk values of target individuals
```

End(Not run)

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