

Package ‘caratINT’

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Type Package

Title Interaction Tests with Covariate-Adaptive Randomization

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Author Likun Zhang [aut, cre], Wei Ma [aut, ths]

Maintainer Likun Zhang <zhanglk6@ruc.edu.cn>

Description This package implements all of the interaction tests in Zhang and Ma (2024) for interaction testing under covariate-adaptive randomization

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base.est.multi	<i>Generate a batch of frequently used quantities to avoid redundancy.</i>
----------------	--

Description

Generate a batch of frequently used quantities to avoid redundancy.

Usage

```
base.est.multi(Y, A, S, X, pi, q)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects.
X	a categorical vector of covariate levels, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.
q	a numeric value indicating the balance level of covariate-adaptive randomizations. not used here.

Value

some frequently used quantities

cat.to.int	<i>Transform categorical variables to Integers 0, 1, 2, ...</i>
------------	---

Description

Transform categorical variables to Integers 0, 1, 2, ...

Usage

```
cat.to.int(categorical_var)
```

Arguments

categorical_var
a categorical variable, e.g, covariate X and stratum S.

Value

The integer froms of the variable.

create.fold	<i>Generate fold indexes of size n used for cross-fitting; first M-1 folds are of equal size</i>
-------------	--

Description

Generate fold indexes of size n used for cross-fitting; first M-1 folds are of equal size

Usage

```
create.fold(n, M = 2)
```

Arguments

n an Integer for sample size
M an Integer for number of folds for M-fold cross-fitting

Value

a vector of p-values produced by different methods.

<code>delta.eff</code>	<i>The semiparametric efficient estimator for interaction effect for continuous X, suppose that Y1_fit and Y0_fit are fitted conditional on X and Z</i>
------------------------	---

Description

The semiparametric efficient estimator for interaction effect for continuous X, suppose that Y1_fit and Y0_fit are fitted conditional on X and Z

Usage

```
delta.eff(Y, A, S, X, pi, Y1_fit, Y0_fit)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects;
X	a numeric vector of covariate values, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.
Y1_fit	a numeric vector of fitted values for Y1 conditioned on covariates, expected to be derived by cross-fitting or using true Y1.
Y0_fit	a numeric vector of fitted values for Y0 conditioned on covariates, expected to be derived by cross-fitting or using true Y0.

Value

The semiparametric efficient estimator for interaction effect.

<code>eff.test.cont</code>	<i>The semiparametric efficient interaction test</i>
----------------------------	--

Description

Testing the interaction effect based on the semiparametric efficient method

Usage

```
eff.test.cont(Y, A, S, X, pi, Y1_fit, Y0_fit)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects.
X	a numeric vector of covariate values, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.
Y1_fit	a numeric vector of fitted values for Y1 conditioned on covariates, expected to be derived by cross-fitting or using true Y1.
Y0_fit	a numeric vector of fitted values for Y0 conditioned on covariates, expected to be derived by cross-fitting or using true Y0.

Value

The two-sided p-value for the test.

generate.R.matrix	<i>Generate contrast matrices for interaction tests for no heterogeneity for over all levels of X.</i>
-------------------	--

Description

Generate contrast matrices for interaction tests for no heterogeneity for over all levels of X.

Usage

```
generate.R.matrix(K)
```

Arguments

K equals the levels of categorical X minus 1, that is, $K = \max(\text{cat.to.int}(X))$.

Value

The contrast matrix R.

mod.test.cont	<i>The modified interaction test</i>
---------------	--------------------------------------

Description

Testing the interaction effect based on the simple linear model and modified variance estimator

Usage

```
mod.test.cont(Y, A, S, X, pi, q)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects.
X	a numeric vector of covariate values, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.
q	a numeric value indicating the balance level of covariate-adaptive randomizations.

Value

The two-sided p-value for the test.

modified.test	<i>The modified interaction test</i>
---------------	--------------------------------------

Description

Testing the interaction effect based on difference in means interaction effect estimator and modified variance estimator

Usage

```
modified.test(Y, A, S, X, pi, q)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects.
X	a categorical vector of covariate levels, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.
q	a numeric value indicating the balance level of covariate-adaptive randomizations. Detailed information can be found in Section 2, Ma et al. (2022) and Zhang and Ma (2024).

Details

Testing the interaction effect based on difference in means. It implements the methods as described in Sections 3.1 and 4.1, Zhang and Ma (2024).

Value

The two-sided p-value for the test.

References

Ma, W., Tu, F., & Liu, H. (2022). Regression analysis for covariate-adaptive randomization: a robust and efficient inference perspective. *Statistics in Medicine*, 41(29), 5645–5661.

Zhang, L. & Ma, W. (2024). Interaction tests with covariate-adaptive randomization. arXiv preprint arXiv:2311.17445.

Examples

```
#The code replicates the simulation setting of Model 2 in Section 5, Zhang and Ma (2024).
N <- 800
pi <- 0.5
q <- pi*(1-pi)
X_star = runif(N, -1, 1)
X_d = ifelse(X_star > 0, 1, 0)
W = rnorm(N,0,2)
W_d = ifelse(W > 0, 1, 0)
error1 = exp(0.5*X_star)*rnorm(N)
error0 = 0.5*exp(0.5*X_star)*rnorm(N)
S <- stratify(X_d, W_d)
X <- X_d
A <- sample(c(0,1),N,replace=TRUE,prob=c(1-pi,pi))
alphavec <- c(5, 4, 0.5, 1.2, 2, 6)
Y0 <- alphavec[2] + exp(alphavec[3]*X_star) + alphavec[5]*W + error0
Y1 <- alphavec[1] + exp((alphavec[3] + alphavec[4])*X_star) + alphavec[5]*W+ alphavec[6] * W *X_star + error1
Y <- Y0*(1-A)+Y1*A
modified.test(Y, A, S, X, pi, q)
```

`mu0.cont`*The stratified mean under control*

Description

The stratified mean under control

Usage

```
mu0.cont(r, A, S)
```

Arguments

- | | |
|----------------|---|
| <code>r</code> | a numeric vector of transformed outcomes. Its length should be the same as the number of subjects. |
| <code>A</code> | a numeric vector of treatment assignments. Its length should be the same as the number of subjects. |
| <code>S</code> | a categorical vector of stratum labels. Its length should be the same as the number of subjects. |

Value

A vector of the stratified means of `r` under control.

`mu1.cont`*The stratified mean under treated*

Description

The stratified mean under treated

Usage

```
mu1.cont(r, A, S)
```

Arguments

- | | |
|----------------|---|
| <code>r</code> | a numeric vector of transformed outcomes. Its length should be the same as the number of subjects. |
| <code>A</code> | a numeric vector of treatment assignments. Its length should be the same as the number of subjects. |
| <code>S</code> | a categorical vector of stratum labels. Its length should be the same as the number of subjects. |

Value

A vector of the stratified means of `r` under treated.

new.test	<i>Modified test for no interaction for binary X</i>
----------	--

Description

Modified test for no interaction for binary X

Usage

```
new.test(Y, A, S, X, pi, q)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects.
X	a categorical vector of covariate levels, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.
q	a numeric value indicating the balance level of covariate-adaptive randomizations.

Value

The two-sided p-value for the test. Asymptotically exact

new.test.multi	<i>Modified test for no interaction for categorical X</i>
----------------	---

Description

Modified test for no interaction for categorical X

Usage

```
new.test.multi(Y, A, S, X, pi, q)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects.
X	a categorical vector of covariate levels, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.
q	a numeric value indicating the balance level of covariate-adaptive randomizations.

Value

The two-sided p-value for the test. Asymptotically exact

old.test	<i>Usual test using Huber White sandwich variance estimator for no interaction for binary X</i>
----------	---

Description

Usual test using Huber White sandwich variance estimator for no interaction for binary X

Usage

```
old.test(Y, A, S, X, pi, q)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects.
X	a categorical vector of covariate levels, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.
q	a numeric value indicating the balance level of covariate-adaptive randomizations.

Value

The two-sided p-value for the test. Can be conservative

old.test.multi	<i>Usual test using Huber White sandwich variance estimator for no interaction for categorical X</i>
----------------	--

Description

Usual test using Huber White sandwich variance estimator for no interaction for categorical X

Usage

```
old.test.multi(Y, A, S, X, pi, q)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects.
X	a categorical vector of covariate levels, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.
q	a numeric value indicating the balance level of covariate-adaptive randomizations.

Value

The two-sided p-value for the test. Can be conservative

ols.test	<i>OLS test for no interaction for binary X</i>
----------	---

Description

OLS test for no interaction for binary X

Usage

```
ols.test(Y, A, S, X, pi, q)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects, not used here.
X	a categorical vector of covariate levels, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum, not used here.
q	a numeric value indicating the balance level of covariate-adaptive randomizations. not used here.

Value

The two-sided p-value for the test. Can be either conservative or anti-conservative

ols.test.cont	<i>OLS test for no interaction for continuous X</i>
---------------	---

Description

OLS test for no interaction for continuous X

Usage

```
ols.test.cont(Y, A, X)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
X	a numeric vector of covariate values, whose treatment-covariate interaction is of interest.

Value

The two-sided p-value for the test. Can be either conservative or anti-conservative

output	<i>p-values for all methods (ols, HW, modified, and efficient) produced by one copy of data suppose that Y1_fit and Y0_fit are fitted conditional on X and Z</i>
--------	--

Description

p-values for all methods (ols, HW, modified, and efficient) produced by one copy of data suppose that Y1_fit and Y0_fit are fitted conditional on X and Z

Usage

```
output(Y, A, S, X, pi, q, Y1_fit, Y0_fit)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects;
X	a numeric vector of covariate values, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.
Y1_fit	a numeric vector of fitted values for Y1 conditioned on covariates, expected to be derived by cross-fitting or using true Y1.
Y0_fit	a numeric vector of fitted values for Y0 conditioned on covariates, expected to be derived by cross-fitting or using true Y0.

Value

a vector of p-values produced by different methods.

strata.test	<i>Stratified-adjusted test for no interaction for binary X</i>
-------------	---

Description

Stratified-adjusted test for no interaction for binary X

Usage

```
strata.test(Y, A, S, X, pi, q)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects.
X	a categorical vector of covariate levels, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.
q	a numeric value indicating the balance level of covariate-adaptive randomizations; actually not used here.

Value

The two-sided p-value for the test. Asymptotically exact and more powerful

strata.test.multi	<i>Stratified-adjusted test for no interaction for categorical X</i>
-------------------	--

Description

Stratified-adjusted test for no interaction for categorical X

Usage

```
strata.test.multi(Y, A, S, X, pi, q)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects.
X	a categorical vector of covariate levels, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.
q	a numeric value indicating the balance level of covariate-adaptive randomizations; actually not used here.

Value

The two-sided p-value for the test. Asymptotically exact and more powerful

stratified.adjusted.test

The stratified-adjusted interaction test

Description

Testing the interaction effect based on stratified-adjusted difference in means interaction effect estimator and stratified-adjusted variance estimator

Usage

```
stratified.adjusted.test(Y, A, S, X, pi)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects.
X	a categorical vector of covariate levels, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.

Details

Testing the interaction effect based on stratified-adjusted difference in means. It implements the methods as described in Sections 3.2 and 4.2, Zhang and Ma (2024).

Value

The two-sided p-value for the test.

References

Zhang, L. & Ma, W. (2024). Interaction tests with covariate-adaptive randomization. arXiv preprint arXiv:2311.17445.

Examples

```
#The code replicates the simulation setting of Model 2 in Section 5, Zhang and Ma (2024).
N <- 800
pi <- 0.5
X_star = runif(N, -1, 1)
X_d = ifelse(X_star > 0, 1, 0)
W = rnorm(N, 0, 2)
W_d = ifelse(W > 0, 1, 0)
error1 = exp(0.5*X_star)*rnorm(N)
error0 = 0.5*exp(0.5*X_star)*rnorm(N)
S <- stratify(X_d, W_d)
```

```
X <- X_d
A <- sample(c(0,1),N,replace=TRUE,prob=c(1-pi,pi))
alphavec <- c(5, 4, 0.5, 1.2, 2, 6)
Y0 <- alphavec[2] + exp(alphavec[3]*X_star) + alphavec[5]*W + error0
Y1 <- alphavec[1] + exp((alphavec[3] + alphavec[4])*X_star) + alphavec[5]*W+ alphavec[6] * W *X_star + error1
Y <- Y0*(1-A)+Y1*A
stratified.adjusted.test(Y, A, S, X, pi)
```

stratify	<i>Stratification based on one or more categorical variables</i>
----------	--

Description

Generate strata by considering all combinations of covariates’ levels

Usage

```
stratify(...)
```

Details

Testing the interaction effect based on difference in means. It implements the methods as described in Sections 3.1 and 4.1, Zhang and Ma (2024).

Value

All level combinations derived from the provided categorical covariates.

Examples

```
#The code shows how to generate strata based on one or more categorical covariates
N <- 800
X_star = runif(N, -1, 1)
X_d = ifelse(X_star > 0, 1, 0)
W = rnorm(N,0,2)
W_d = ifelse(W > 0, 1, 0)
stratify(X_d, W_d)
```

tau.strata	<i>Stratified-adjusted estimate for interaction effect for binary X</i>
------------	---

Description

Stratified-adjusted estimate for interaction effect for binary X

Usage

```
tau.strata(Y, A, S, X, pi, q)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects.
X	a categorical vector of covariate levels, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum; not used here.
q	a numeric value indicating the balance level of covariate-adaptive randomizations; not used here.

Value

The stratified-adjusted point estimate for interaction effect.

tau.strata.multi	<i>Stratified-adjusted estimate for interaction effect for categorical X</i>
------------------	--

Description

Stratified-adjusted estimate for interaction effect for categorical X

Usage

```
tau.strata.multi(Y, A, S, X, pi, q)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects.
X	a categorical vector of covariate levels, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum; not used here.
q	a numeric value indicating the balance level of covariate-adaptive randomizations; not used here.

Value

The stratified-adjusted point estimate for interaction effect.

tau.t	<i>Simple difference-in-difference estimate for interaction effect for binary X</i>
-------	---

Description

Simple difference-in-difference estimate for interaction effect for binary X

Usage

```
tau.t(Y, A, S, X, pi, q)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects; not used here.
X	a categorical vector of covariate levels, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum; not used here.
q	a numeric value indicating the balance level of covariate-adaptive randomizations; not used here.

Value

The usual point estimate for interaction effect.

tau.t.multi	<i>Simple difference-in-difference estimate for interaction effect for categorical X</i>
-------------	--

Description

Simple difference-in-difference estimate for interaction effect for categorical X

Usage

```
tau.t.multi(Y, A, S, X, pi, q)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects; not used here.
X	a categorical vector of covariate levels, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum; not used here.
q	a numeric value indicating the balance level of covariate-adaptive randomizations; not used here.

Value

The usual point estimate for interaction effect.

transform.outcome	<i>The transformed outcomes used for interaction tests for continuous X</i>
-------------------	---

Description

The transformed outcomes used for interaction tests for continuous X

Usage

```
## S3 method for class 'outcome'
transform(Y, A, S, X, pi, q)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects;
X	a numeric vector of covariate values, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.
q	a numeric value indicating the balance level of covariate-adaptive randomizations.

Value

A vector of the transformed outcomes $r_i = r_i(1)A_i + r_i(0)(1-A_i)$.

usual.test

*The usual interaction test***Description**

Testing the interaction effect based on difference in means interaction effect estimator and heteroscedasticity-robust variance estimator (Huber–White)

Usage

```
usual.test(Y, A, S, X, pi)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects.
X	a categorical vector of covariate levels, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.

Details

Testing the interaction effect based on difference in means. It implements the methods as described in Sections 3.1 and 4.1, Zhang and Ma (2024).

Value

The two-sided p-value for the test.

References

Zhang, L. & Ma, W. (2024). Interaction tests with covariate-adaptive randomization. arXiv preprint arXiv:2311.17445.

Examples

```
#The code replicates the simulation setting of Model 2 in Section 5, Zhang and Ma (2024).
N <- 800
pi <- 0.5
X_star = runif(N, -1, 1)
X_d = ifelse(X_star > 0, 1, 0)
W = rnorm(N,0,2)
W_d = ifelse(W > 0, 1, 0)
error1 = exp(0.5*X_star)*rnorm(N)
error0 = 0.5*exp(0.5*X_star)*rnorm(N)
S <- stratify(X_d, W_d)
X <- X_d
A <- sample(c(0,1),N,replace=TRUE,prob=c(1-pi,pi))
```

```

alphavec <- c(5, 4, 0.5, 1.2, 2, 6)
Y0 <- alphavec[2] + exp(alphavec[3]*X_star) + alphavec[5]*W + error0
Y1 <- alphavec[1] + exp((alphavec[3] + alphavec[4])*X_star) + alphavec[5]*W+ alphavec[6] * W *X_star + error1
Y <- Y0*(1-A)+Y1*A
usual.test(Y, A, S, X, pi)

```

usual.test.cont	<i>The usual interaction test</i>
-----------------	-----------------------------------

Description

Testing the interaction effect based on the simple linear model and heteroscedasticity-robust variance estimator (Huber–White)

Usage

```
usual.test.cont(Y, A, X)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
X	a numeric vector of covariate values, whose treatment-covariate interaction is of interest.

Value

The two-sided p-value for the test.

var.eff	<i>The semiparametric efficiency bound estimator for interaction effect for continuous X, suppose that Y1_fit and Y0_fit are fitted conditional on X and Z</i>
---------	--

Description

The semiparametric efficiency bound estimator for interaction effect for continuous X, suppose that Y1_fit and Y0_fit are fitted conditional on X and Z

Usage

```
var.eff(Y, A, S, X, pi, Y1_fit, Y0_fit)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects;
X	a numeric vector of covariate values, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.
Y1_fit	a numeric vector of fitted values for Y1 conditioned on covariates, expected to be derived by cross-fitting or using true Y1.
Y0_fit	a numeric vector of fitted values for Y0 conditioned on covariates, expected to be derived by cross-fitting or using true Y0.

Value

The semiparametric efficiency bound estimator for interaction effect.

var.heter	<i>Huber White variance estimator for interaction effect for binary X</i>
-----------	---

Description

Huber White variance estimator for interaction effect for binary X

Usage

```
var.heter(Y, A, S, X, pi, q)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects; not used here.
X	a categorical vector of covariate levels, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum; not used here.
q	a numeric value indicating the balance level of covariate-adaptive randomizations; not used here.

Value

The Huber White variance estimator for interaction effect.

var.heter.multi.inv	<i>The inverse of Huber White variance estimator for interaction effect for categorical X</i>
---------------------	---

Description

The inverse of Huber White variance estimator for interaction effect for categorical X

Usage

```
var.heter.multi.inv(Y, A, S, X, pi, q)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects; not used here.
X	a categorical vector of covariate levels, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum; not used here.
q	a numeric value indicating the balance level of covariate-adaptive randomizations; not used here.

Value

The inverse of Huber White variance estimator for $R\backslash\text{hatau}$.

var.modified	<i>The modified variance estimator for interaction effect for binary X</i>
--------------	--

Description

The modified variance estimator for interaction effect for binary X

The modified variance estimator for interaction effect for continuous X

Usage

```
var.modified(Y, A, S, X, pi, q)
```

```
var.modified(Y, A, S, X, pi, q)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects;
X	a numeric vector of covariate values, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.
q	a numeric value indicating the balance level of covariate-adaptive randomizations.

Value

The modified variance estimator for interaction effect.
The modified variance estimator for interaction effect.

var.modified.multi.inv

The inverse of modified variance estimator for interaction effect for categorical X

Description

The inverse of modified variance estimator for interaction effect for categorical X

Usage

```
var.modified.multi.inv(Y, A, S, X, pi, q)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects.
X	a categorical vector of covariate levels, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.
q	a numeric value indicating the balance level of covariate-adaptive randomizations.

Value

The inverse of modified variance estimator for $R\backslash\text{hatau}$.

var.strata	<i>The stratified-adjusted variance estimator for interaction effect for binary X</i>
------------	---

Description

The stratified-adjusted variance estimator for interaction effect for binary X

Usage

```
var.strata(Y, A, S, X, pi, q)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects;
X	a categorical vector of covariate levels, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.
q	a numeric value indicating the balance level of covariate-adaptive randomizations.

Value

The stratified-adjusted variance estimator for interaction effect.

var.strata.multi.inv	<i>The stratified-adjusted variance estimator for interaction effect for categorical X</i>
----------------------	--

Description

The stratified-adjusted variance estimator for interaction effect for categorical X

Usage

```
var.strata.multi.inv(Y, A, S, X, pi, q)
```

Arguments

Y	a numeric vector of observed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects;
X	a categorical vector of covariate levels, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.
q	a numeric value indicating the balance level of covariate-adaptive randomizations.

Value

The inversed of the stratified-adjusted variance estimator for $R\hat{\tau}$.

zeta.A.r	<i>The third component in the asymptotic variance of the modified method</i>
----------	--

Description

The third component in the asymptotic variance of the modified method

Usage

```
zeta.A.r(r, A, S, X, pi, q)
```

Arguments

r	a numeric vector of transformed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects.
X	a numeric vector of covariate values, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.
q	a numeric value indicating the balance level of covariate-adaptive randomizations.

Value

A numeric value for the third component.

zeta.H.r	<i>The second component in the asymptotic variance of the modified method</i>
----------	---

Description

The second component in the asymptotic variance of the modified method

Usage

```
zeta.H.r(r, A, S, X, pi, q)
```

Arguments

r	a numeric vector of transformed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects.
X	a numeric vector of covariate values, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.
q	a numeric value indicating the balance level of covariate-adaptive randomizations.

Value

A numeric value for the second component.

zeta.tilde.r	<i>The first component in the asymptotic variance of the modified method</i>
--------------	--

Description

The first component in the asymptotic variance of the modified method

Usage

```
zeta.tilde.r(r, A, S, X, pi, q)
```

Arguments

r	a numeric vector of transformed outcomes. Its length should be the same as the number of subjects.
A	a numeric vector of treatment assignments. Its length should be the same as the number of subjects.
S	a categorical vector of stratum labels. Its length should be the same as the number of subjects.
X	a numeric vector of covariate values, whose treatment-covariate interaction is of interest.
pi	a numeric value for the target treatment proportion in each stratum.
q	a numeric value indicating the balance level of covariate-adaptive randomizations.

Value

A numeric value for the first component.

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