Package ‘match2C’

May 9, 2021

Type Package
Title Match One Sample using Two Criteria
Version 1.1.1
Description Multivariate matching in observational studies typically has two goals: 1. to construct
treated and control groups that have similar distribution of observed covariates and 2. to produce
matched pairs or sets that are homogeneous in a few priority variables. This package implements
a network-flow-based method built around a tripartite graph that can simultaneously achieve both goals.
A detailed explanation of the workflow and numerous examples are given in the vignette.

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R topics documented:

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NewPackage-package

A short title line describing what the package does

Description
A more detailed description of what the package does. A length of about one to five lines is recommended.

Details
This section should provide a more detailed overview of how to use the package, including the most important functions.

Author(s)
Your Name, email optional.
Maintainer: Your Name <your@email.com>

References
This optional section can contain literature or other references for background information.

See Also
Optional links to other man pages

Examples
## Not run:
## Optional simple examples of the most important functions
## These can be in \dontrun{} and \donttest{} blocks.

## End(Not run)
check_balance

Description
This function checks the overall balance after statistical matching and plots the distribution of the propensity score in the treated group, the control group, and the matched control group.

Usage
check_balance(Z, match_object, cov_list, plot_propens, propens)

Arguments
- **Z**: A vector of treatment indicator.
- **match_object**: An object returned by match_2C or match_2C_mat or match_2C_list.
- **cov_list**: A vector of names of covariates as appeared in the original dataset.
- **plot_propens**: Post-matching distribution of the estimated propensity scores in two groups is plotted if TRUE; FALSE by default.
- **propens**: NULL by default. If plot_propens = TRUE, then a vector of estimated propensity scores satisfying length(propens) = length(Z) needs to be supplied.

Value
This function returns a data frame of the overall balance after statistical matching. We tabulate the mean of each covariate in the cov_list in the treated group and control groups after matching, and calculate their standardized differences. Standardized difference is defined as the mean difference divided by the pooled standard error before matching.

construct_outcome

Description
This function constructs the output given the relaxsolution to the associated network flow problem and the original dataset.

Usage
construct_outcome(res, dist_list_1, Z, dataset, controls = 1)
create_list_from_mat

Create a list representation of a distance matrix.

Description

This function creates a “list representation” of a treatment-by-control distance matrix.

Usage

create_list_from_mat(
  Z,
  dist_mat,
  p = NULL,
  caliper = NULL,
  k = NULL,
  penalty = Inf
)

Arguments

Z A length (n = n_t + n_c) vector of treatment indicators.
dist_mat A treatment-by-control (n_t-by-n_c) distance matrix.
p A vector of length (n_t + n_c) on which caliper applies (e.g. propensity scores)
caliper Size of the caliper.
k Connect each treated to the nearest k controls
penalty Penalty for violating the caliper. Set to Inf by default.
**create_list_from_scratch**

Create a sparse list representation of treatment-to-control distance matrix with a caliper.

**Details**

This function creates a list representation of a treatment-by-control network. The list representation can be made sparse using a user-specified caliper. A list representation of a treatment-by-control distance matrix consists of the following arguments:

- `start_n`: a vector containing the node numbers of the start nodes of each arc in the network.
- `end_n`: a vector containing the node numbers of the end nodes of each arc in the network.
- `d`: a vector containing the integer cost of each arc in the network.

Node 1, 2, ..., n_t are n_t treatment nodes; n_t + 1, n_t + 2, ..., n_t + n_c are n_c control nodes. `start_n`, `end_n`, and `d` should have the same lengths, all of which equal to the number of edges.

There are two options for users to make a network sparse. Option caliper is a value applied to the vector p to avoid connecting treated to controls whose covariate or propensity score defined by p is outside p +/- caliper. Second, within a specified caliper, sometimes there are still too many controls connected to each treated, and we can further trim down this number up to k by restricting our attention to the k nearest (in p) to each treated.

By default a hard caliper is applied, i.e., option penalty is set to Inf by default. Users may make the caliper a soft one by setting penalty to a large yet finite number.

**Value**

This function returns a list that consists of three arguments: `start_n`, `end_n`, and `d`, as described above.

```r
create_list_from_scratch(Z, X, exact = NULL, soft_exact = FALSE, p = NULL, caliper_low = NULL, caliper_high = NULL, k = NULL, alpha = 1)
```

**Description**

This function takes in a n-by-p matrix of observed covariates, a length-n vector of treatment indicator, a caliper, and construct a possibly sparse list representation of the distance matrix.

**Usage**

```r
create_list_from_scratch(Z, X, exact = NULL, soft_exact = FALSE, p = NULL, caliper_low = NULL, caliper_high = NULL, k = NULL, alpha = 1)
```
penalty = Inf,
  method = "maha",
  dist_func = NULL
)

Arguments

Z
A length-n vector of treatment indicator.

X
A n-by-p matrix of covariates.

exact
A vector of strings indicating which variables need to be exactly matched.

soft_exact
If set to TRUE, the exact constraint is enforced up to a large penalty.

p
A length-n vector on which a caliper applies, e.g. a vector of propensity score.

caliper_low
Size of caliper low.

caliper_high
Size of caliper high.

k
Connect each treated to the nearest k controls. See details section.

alpha
Tuning parameter.

penalty
Penalty for violating the caliper. Set to Inf by default.

method
Method used to compute treated-control distance

dist_func
A user-specified function that compute treatate-control distance. See details section.

Details

Currently, there are 4 methods implemented in this function: 'maha' (Mahalanobis distance), robust maha' (robust Mahalanobis distance), '0/1' (distance = 0 if and only if covariates are the same), 'Hamming' (Hamming distance).

Users can also supply their own distance function by setting method = 'other' and using the argument "dist_func". "dist_func" is a user-supplied distance function in the following format: dist_func(controls, treated), where treated is a length-p vector of covaraites and controls is a n_c-by-p matrix of covariates. The output of function dist_func is a length-n_c vector of distance between each control and the treated.

There are two options for users to make a network sparse. Option caliper is a value applied to the vector p to avoid connecting treated to controls whose covariate or propensity score defined by p is outside p +/- caliper. Second, within a specified caliper, sometimes there are still too many controls connected to each treated, and we can further trim down this number up to k by restricting our attention to the k nearest (in p) to each treated.

By default a hard caliper is applied, i.e., option penalty is set to Inf by default. Users may make the caliper a soft one by setting penalty to a large yet finite number.

Value

This function returns a list of three objects: start_n, end_n, and d. See documentation of function "create_list_from_mat" for more details.
Examples

# We first prepare the input X, Z, propensity score

attach(dt_Rouse)
X = cbind(female, black, bytest, dadeduc, momeduc, fincome)
Z = IV
propensity = glm(IV~female+black+bytest+dadeduc+momeduc+fincome,
    family=binomial)$fitted.values
detach(dt_Rouse)

# Create distance lists with built-in options.
# Mahalanobis distance with propensity score caliper = 0.05
# and k = 100.

dist_list_pscore_maha = create_list_from_scratch(Z, X, p = propensity,
    caliper_low = 0.05, k = 100, method = 'maha')

# More examples, including how to use a user-supplied
# distance function, can be found in the vignette.

create_list_from_scratch_overall

Create a sparse list representation of treated-to-control distance ma-
trix with a fixed number caliper with L1-distance.

Description

This function takes in a n-by-p matrix of observed covariates, a length-n vector of treatment in-
dicator, a caliper, and construct a possibly sparse list representation of the distance matrix with
Mahalanobis distance. Note that this function is of limited interest to most users.

Usage

create_list_from_scratch_overall(  
    Z,
    X,
    exact = NULL,
    soft_exact = FALSE,
    p = NULL,
    caliper_low = NULL,
    caliper_high = NULL,
    k = NULL,
    penalty = Inf,
    dist_func = NULL
)
Arguments

- **Z**: A length-n vector of treatment indicator.
- **X**: A n-by-p matrix of covariates.
- **exact**: A vector of strings indicating which variables are to be exactly matched.
- **soft_exact**: If set to TRUE, the exact constraint is enforced up to a large penalty.
- **p**: A length-n vector on which a caliper applies, e.g. a vector of propensity score.
- **caliper_low**: Size of caliper_inf.
- **caliper_high**: Size of caliper_sup.
- **k**: Connect each treated to the nearest k controls
- **penalty**: Penalty for violating the caliper. Set to Inf by default.
- **dist_func**: A function used to calculate distance

Value

This function returns a list of three objects: start_n, end_n, and d. See documentation of function “create_list_from_mat” for more details.

---

**dt_Rouse**

*Rouse (1995) dataset*

**Description**

Variables of the dataset is as follows:

- **educ86**: Years of education since 1986.
- **twoyr**: Attending a two-year college immediately after high school.
- **female**: Gender: 1 if female and 0 otherwise.
- **black**: Race: 1 if African American and 0 otherwise.
- **hispanic**: Race: 1 if Hispanic and 0 otherwise.
- **bytest**: Test score.
- **fincome**: Family income.
- **fincommiss**: Missingness indicator for family income.
- **IV**: Instrumental variable: encouragement to attend a two-year college.
- **dadeduc**: Dad’s education: College - 2; Some college - 1; Neither - 0.
- **momeduc**: Mom’s education: College - 2; Some college - 1; Neither - 0.

**Usage**

data(dt_Rouse)
force_control

Format

A data frame with 3037 rows, 8 observed variables, 1 binary instrumental variable, 1 treatment, and 1 continuous response.

Source

ss

---

force_control  Force including certain controls in the final matched samples.

---

Description

This function processes the given distance list by adding certain zero-cost edges so that the user-specified controls are forced into the final matched samples. This function is of little interest to most users.

Usage

force_control(dist_list, Z, include)

Arguments

dist_list  A distance_list object.
Z  A length-n vector of treatment indicator.
include  A binary vector indicating which controls must be included (length(include) = sum(1-Z)).

Value

This function returns a distance list object with added edges.

---

match_2C  Optimal Matching with Two Criteria.

---

Description

This function performs an optimal statistical matching that sequentially balances the nominal levels (near-fine balance), the marginal distribution of the propensity score, and the total within-matched-pair Mahalanobis distance.
Usage

```r
match_2C(
  Z,
  X,
  propensity,
  dataset,
  method = "maha",
  exact = NULL,
  caliper_left = 1,
  caliper_right = 1,
  k_left = NULL,
  k_right = NULL,
  fb_var = NULL,
  controls = 1,
  include = NULL
)
```

Arguments

- `Z` A length-n vector of treatment indicator.
- `X` A n-by-p matrix of covariates with column names.
- `propensity` A vector of estimated propensity score (length(propensity) = length(Z)).
- `dataset` Dataset to be matched.
- `method` Method used to compute treated-control distance on the left. The default is the Mahalanobis distance.
- `exact` A vector of strings indicating which variables need to be exactly matched.
- `caliper_left` Size of caliper on the left network.
- `caliper_right` Size of caliper on the right network.
- `k_left` Connect each treated to k_left controls closest in the propensity score in the left network.
- `k_right` Connect each treated to k_right controls closest in the propensity score in the right network.
- `fb_var` A vector giving names of variables in matrix X to be finely balanced.
- `controls` Number of controls matched to each treated. Default is 1.
- `include` A binary vector indicating which controls must be included (length(include) = sum(1-Z)).

Value

This function returns a list of three objects including the feasibility of the matching problem and the matched controls organized in different formats. See the documentation of the function construct_outcome or the vignette for more details.
Examples

# We first prepare the input X, Z, propensity score
attach(dt_Rouse)
X = cbind(female, black, bytest, dadeduc, momeduc, fincome)
Z = IV
propensity = glm(IV ~ female + black + bytest + dadeduc + momeduc + fincome,
               family = binomial)$fitted.values
detach(dt_Rouse)

matching_output_double_calipers = match_2C(Z = Z, X = X,
                                          propensity = propensity,
                                          caliper_left = 0.05, caliper_right = 0.05,
                                          k_left = 100, k_right = 100,
                                          dataset = dt_Rouse)

# Please refer to the vignette for many more examples.

match_2C_list

Perform a pair (or 1:k) matching with two user-specified list representations of distance matrices.

Description

This function performs a pair-matching using (at most) two user-specified distance matrices in their (possibly sparse) list representations. For more details on “list representations” of a treatment-by-control distance matrix, see the documentation of the function “create_list_from_mat”.

Usage

match_2C_list(
  Z,
  dataset,
  dist_list_1,
  dist_list_2 = NULL,
  lambda = 1000,
  controls = 1,
  overflow = FALSE
)

Arguments

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td>A length-n vector of treatment indicator.</td>
</tr>
<tr>
<td>dataset</td>
<td>dataset to be matched.</td>
</tr>
<tr>
<td>dist_list_1</td>
<td>A (possibly sparse) list representation of treatment-by-control distance matrix.</td>
</tr>
</tbody>
</table>
match_2C_mat

- **dist_list_2**: A second (possibly sparse) list representation of treatment-by-control distance matrix.
- **lambda**: A penalty that does a trade-off between two parts of the network.
- **controls**: Number of controls matched to each treated. Default is set to 1.
- **overflow**: A logical value indicating if overflow protection is turned on.

### Details

This function is designed for more experienced and sophisticated R users. Instead of providing possibly dense treatment-by-control distance matrices that take up a lot of memories, users may simply provide two lists that specifies information of edges: their starting points, ending points, capacity, and cost. For more information on list representations of a distance matrix, see the documentation of the function “create_list_from_mat” and “create_list_from_scratch”. Note that by setting `dist_list_2 = NULL`, the usual matching framework is restored.

### Value

This function returns the same object as function `match_2C_mat`.

---

**match_2C_mat**

Perform a pair matching using two user-specified distance matrices.

### Description

This function performs a pair-matching using two user-specified distance matrices and two calipers. Typically one distance matrix is used to minimize matched-pair differences, and a second distance matrix is used to enforce constraints on marginal distributions of certain variables.

### Usage

```r
match_2C_mat(
  Z,
  dataset,
  dist_mat_1,
  dist_mat_2,
  lambda,
  controls = 1,
  p_1 = NULL,
  caliper_1 = NULL,
  k_1 = NULL,
  p_2 = NULL,
  caliper_2 = NULL,
  k_2 = NULL,
  penalty = Inf,
  overflow = FALSE
)
```
Arguments

- **Z**: A length-n vector of treatment indicator.
- **dataset**: The original dataset.
- **dist_mat_1**: A user-specified treatment-by-control (n_t-by-n_c) distance matrix.
- **dist_mat_2**: A second user-specified treatment-by-control (n_t-by-n_c) distance matrix.
- **lambda**: A penalty that controls the trade-off between two parts of the network.
- **controls**: Number of controls matched to each treated.
- **p_1**: A length-n vector on which caliper_1 applies, e.g., a vector of propensity score.
- **caliper_1**: Size of caliper_1.
- **k_1**: Maximum number of controls each treated is connected to in the first network.
- **p_2**: A length-n vector on which caliper_2 applies, e.g., a vector of propensity score.
- **caliper_2**: Size of caliper_2.
- **k_2**: Maximum number of controls each treated is connected to in the second network.
- **penalty**: Penalty for violating the caliper. Set to Inf by default.
- **overflow**: A logical value indicating if overflow protection is turned on.

Details

This function performs a pair matching via a two-part network. The first part is a network whose treatment-to-control distance matrix is supplied by dist_mat_1. The second part of the network is constructed using distance matrix specified by dist_mat_2. Often, the first part of the network is used to minimize total treated-to-control matched pair distances, and the second part is used to enforce certain marginal constraints.

The function constructs two list representations of distance matrices, possibly using the caliper. caliper_1 is applied to p_1 (caliper_2 applied to p_2) in order to construct sparse list representations. For instance, a caliper equal to 0.2 (caliper_1 = 0.2) applied to the propensity score (p_1).

lambda is a penalty, or a tuning parameter, that balances these two objectives. When lambda is very large, the network will first minimize the second part of network and then the first part.

Value

This function returns a list of three objects including the feasibility of the matching problem and the matched controls organized in different formats. See the documentation of the function construct_outcome or the tutorial for more details.

Examples

```r
## Not run:
To run the following code, one needs to first install
and load the package optmatch.

# We first prepare the input X, Z, propensity score
```
```r
#attach(dt_Rouse)
#X = cbind(female, black, bytest, dadeduc, momeduc, fincome)
#Z = IV
#propensity = glm(IV ~ female + black + bytest + dadeduc + momeduc + fincome,
#family = binomial)$fitted.values
#n_t = sum(Z)
#n_c = length(Z) - n_t
#dt_Rouse$propensity = propensity
#detach(dt_Rouse)

# Next, we use the match_on function in optmatch to create two treated-by-control distance matrices.

#library(optmatch)
# dist_mat_1 = match_on(IV ~ female + black + bytest + dadeduc + momeduc + fincome,
# method = 'mahalanobis', data = dt_Rouse)
# dist_mat_2 = match_on(IV ~ female, method = 'euclidean', data = dt_Rouse)

# Feed two distance matrices to the function match_2C_mat without caliper and a large penalty lambda to enforce (near-)fine balance.

#matching_output = match_2C_mat(Z, dt_Rouse, dist_mat_1, dist_mat_2,
# lambda = 10000, p_1 = NULL, p_2 = NULL)

# For more examples, please consult the RMarkdown tutorial.

## End(Not run)
```

---

**revert_dist_list_cpp**

*Revert a treated-to-control distance list.*

### Description

Revert a treated-to-control distance list.

### Usage

```r
revert_dist_list_cpp(n_t, n_c, startn, endn, d)
```

### Arguments

- **n_t**: Number of treated units
- **n_c**: Number of control units
- **startn**: Vector of starting nodes of edges
- **endn**: Vector of ending nodes of edges
- **d**: Vector of cost associated with edges
**solve_network_flow**

Solve a network flow problem.

**Description**

This function solves network flow optimization problems by calling the RELAX-IV algorithm implemented in FORTRAN by Dimitri Bertsekas and Paul Tseng, and made available by Sam Pimentel in the package rcbalance.

**Usage**

```r
solve_network_flow(net)
```

**Arguments**

- `net` A list of five vectors: startn, endn, ucap, cost, b.

**Details**

This function is of limited interest to users.

**Value**

If the problem is feasible, function returns a list with the following elements: crash: an integer, equal to zero if the algorithm ran correctly and equal to 1 if it crashed. feasible: an integer, equal to zero if the problem is not feasible. x: a vector equal in length to the number of arcs in argument problem net, giving in each coordinate the number of units of flow passing across the corresponding edge in the optimal network flow. If the problem is not feasible, it returns "Not feasible."

**stitch_two_nets**

Stitch two treated-to-control networks into one two-part networks.

**Description**

This function takes as inputs two networks and one penalty lambda, and constructs one two-part network out of them.

**Usage**

```r
stitch_two_nets(net1, net2, lambda, controls = 1, overflow = FALSE)
```
treated_control_net

Arguments

- net1: A list of five vectors: startn, endn, ucap, cost, b.
- net2: A list of five vectors: startn, endn, ucap, cost, b.
- lambda: A penalty.
- controls: Number of controls matched to each treated.
- overflow: A logical value indicating if overflow protection is turned on.

Details

This function is of limited interest to users. Once overflow is set to TRUE, each control in the first network will be directly connected to the sink at a large cost, so that the network flow problem is feasible as long as the first part is feasible.

Value

This function returns a list of five vectors: startn, endn, ucap, cost, b.

Description

This function takes in a list representation of distance matrix and create a network structure to be solved.

Usage

treated_control_net(n_t, n_c, dist_list, controls = 1)

Arguments

- n_t: Number of treated subjects.
- n_c: Number of controls.
- dist_list: A list representation of the distance matrix.
- controls: Number of controls matched to each treated.

Details

dist_list is a list consisting of the following three elements: start_n: the starting nodes for all edges, end_n: the ending nodes for all edges, d: distance of all treated-control edges. Function create_dist_list in this package constructs such a list representation given a user-specified distance function.

Value

This function returns a list of five vectors: startn, endn, ucap, cost, b.
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