Package ‘PUMP’

February 9, 2022

Type Package

Title Power Under Multiplicity Project

Version 1.0.0

Description
Estimates power, minimum detectable effect size (MDES) and sample size requirements. The context is multilevel randomized experiments with multiple outcomes. The estimation takes into account the use of multiple testing procedures. Development of this package was supported by a grant from the Institute of Education Sciences (R305D170030). For a full package description, including a detailed technical appendix, see <arXiv:2112.15273>.

URL https://github.com/MDRCNY/PUMP

BugReports https://github.com/MDRCNY/PUMP/issues

Depends R (>= 3.5.0)

Imports dplyr, ggplot2, ggpubr, here, future, magrittr, mvtnorm, parallel, purrr, randomizr, readr, rlang, stats, stringr, tibble, tidyr, tidyselect

Suggests testthat, kableExtra, knitr, furrr, PowerUpR (>= 1.1.0)

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Encoding UTF-8

RoxygenNote 7.1.2

VignetteBuilder knitr

NeedsCompilation no

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Repository CRAN

Date/Publication 2022-02-09 09:50:05 UTC
calc_df

**Description**

Given sample sizes, return the used degrees of freedom (frequently conservative) for the design and model.

**Usage**

```r
calc_df(d_m, J, K, nbar, numCovar.1, numCovar.2, numCovar.3, validate = TRUE)
```
**convert_params**

**Description**

Converts user-provided parameters such as ICC and omega into data-generating parameters that can produce simulated data, such as variance values and covariate coefficients.

This function is beyond the main scope of calculating power, and is instead used for simulating data. For more info on use, see the simulation vignette.

**Usage**

```r
convert_params(model.params.list)
```

**Arguments**

- `model.params.list`
  - list; model parameters.

**Value**

- list; data-generating parameters.
**gen_assignments**

*Generates school and district assignments (simulation function)*

**Description**

Generates simple default schools and districts IDs for individual students for the purpose of simulations. This assumes equal sized schools in equal sized districts.

This function is beyond the main scope of calculating power, and is instead used for simulating data. For more info on use, see the simulation vignette.

**Usage**

```r
gen_assignments(J, K, nbar)
```

**Arguments**

- `J`: scalar; number of schools per district.
- `K`: scalar; number of districts.
- `nbar`: scalar; number of individuals per school.

**Value**

list; school and district assignments (S.id, D.id) for each individual.

---

**gen_corr_matrix**

*Generate correlation matrix (simulation function)*

**Description**

Generate correlation matrix (simulation function)

**Usage**

```r
gen_corr_matrix(M, rho.scalar)
```

**Arguments**

- `M`: scalar; dimension of matrix.
- `rho.scalar`: scalar; rho value.

**Value**

matrix; M x M correlation matrix with rho.scalar as diagonal.
**gen_full_data**

*Generate simulated multi-level data (simulation function)*

**Description**

Generates simulated data for multi-level RCTs for pump-supported designs and models for both unobserved and observed potential outcomes.

Takes in a list of necessary data-generating parameters.

This function is beyond the main scope of calculating power, and is instead used for simulating data. For more info on use, see the simulation vignette.

**Usage**

```r
gen_full_data(dgp.params.list)
```

**Arguments**

- `dgp.params.list`: list of data generating parameters.

**Value**

list; potential outcomes given control \(y_0\), treatment \(y_1\), covariates \(V_k, X_{jk}, C_{ijk}\).

---

**gen_T.x**

*Generate treatment assignment vector (simulation function)*

**Description**

Given a RCT design and supporting information, generates treatment assignments for each student.

This function is beyond the main scope of calculating power, and is instead used for simulating data. For more info on use, see the simulation vignette.

**Usage**

```r
gen_T.x(d_m, S.id, D.id, nbar, Tbar)
```

**Arguments**

- `d_m`: string; design and model.
- `S.id`: vector; school assignments.
- `D.id`: vector; district assignments.
- `nbar`: scalar; number of level 1 units.
- `Tbar`: scalar; probability of treatment assignment.
**Value**

vector; treatment assignments for each unit.

---

**gen_Yobs**

*Generate observed outcomes (simulation function)*

**Description**

Takes in a full dataset of both observed and latent potential outcomes and the treatment assignment vector, and returns only the observed outcomes.

This function is beyond the main scope of calculating power, and is instead used for simulating data. For more info on use, see the simulation vignette.

**Usage**

```r
gen_Yobs(full.data, T.x)
```

**Arguments**

- `full.data`: data.frame; full dataset of potential outcomes.
- `T.x`: vector; binary assignment to treat/control.

**Value**

vector; observed outcomes

---

**get_power_results**

*Calculates different definitions of power (support function)*

**Description**

This function takes in a matrix of adjusted p-values and unadjusted p-values and outputs different types of power.

This function is mostly for internal use, but may be of interest to users who wish to calculate power on their own.

**Usage**

```r
get_power_results(
  adj.pval.mat,  # Adjusted p-values matrix
  unadj.pval.mat,  # Unadjusted p-values matrix
  ind.nonzero,  # Indicator for non-zero outcomes
  alpha,  # Significance level
  drop.zero.outcomes = TRUE,  # Drop zero outcomes
  adj = TRUE  # Adjust for multiple testing
)
```
parse_d_m

Arguments

adj.pval.mat  matrix; adjusted p-values, columns are outcomes
unadj.pval.mat matrix; unadjusted p-values, columns are outcomes
ind.nonzero  vector; which outcomes are nonzero.
alpha  scalar; the family wise error rate (FWER).
drop.zero.outcomes  logical; whether to report power results for outcomes with MDES = 0.
adj  logical; whether p-values are unadjusted or not.

Value

data frame; power results for individual, minimum, complete power.

Description

Returns number of levels and model at each level. See pump_info(Context to get a list of supported d_ms.

Usage

parse_d_m(d_m)

Arguments

d_m  string; context to parse.

Value

list; list of features including number of levels, level of randomization, etc.

Examples

supported <- pump_info(comment = FALSE)$Context
parse_d_m( supported$d_m[4] )
**plot.pumpgridresult**  
*Plot a pump grid result object (result function)*

**Description**

Plots grid results across values of a single parameter, specified by the user using var.vary, for a single definition of power, specified by power.definition. If multiple things vary in the grid, the outcome (power, mdes, or sample size) will be averaged (marginalized) across the other varying factors. This treats the grid as a multifactor simulation, with this showing the "main effect" of the specified parameter.

**Usage**

```r
## S3 method for class 'pumpgridresult'
plot(
  x,
  power.definition = NULL,
  var.vary = NULL,
  lines = TRUE,
  include.title = FALSE,
  ...
)
```

**Arguments**

- `x`: pumpgridresult object.
- `power.definition`: string; definition of power to plot. If NULL, plot all definitions as a facet wrap.
- `var.vary`: string; variable to vary on X axis. If NULL, and only one thing varies, then it will default to single varying parameter.
- `lines`: logical; TRUE means connect dots with lines on the plots. FALSE means no lines.
- `include.title`: logical; whether to include/exclude title (if planning a facet wrap, for example).
- `...`: additional parameters.

**Value**

- `plot`: a ggplot object of outcome across parameter values.

**Examples**

```r
g <- pump_power_grid(d_m = "d3.2_m3ff2rc", MTP = c("HO", "BF"), MDES = 0.10, J = seq(5, 10, 1), M = 5, K = 7, nbar = 58,
Tbar = 0.50, alpha = 0.15, numCovar.1 = 1, numCovar.2 = 1, R2.1 = 0.1, R2.2 = 0.7,
ICC.2 = 0.25, ICC.3 = 0.25, rho = 0.4, tnum = 500)
plot(g, power.definition = 'min1')
```
plot.pumpresult  

Plot a single scenario pump object (result function)

Description

Works on an object returned by pump_power(), and visualizes different definitions of power across MTPs. This function does not apply to pump_mdes() or pump_sample() objects, as these functions only return a single value.

Usage

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

Arguments

x  
pumpresult object.

...  
additional parameters.

Value

plot; a ggplot object of power across different definitions.

Examples

pp1 <- pump_power(d_m = "d2.2_m2rc", MTP = 'HO',
  nbar = 50, J = 20, M = 8, numZero = 5,
  MDES = 0.30, Tbar = 0.5, alpha = 0.05, two.tailed = FALSE,
  numCovar.1 = 1, numCovar.2 = 1, R2.1 = 0.1, R2.2 = 0.7,
  ICC.2 = 0.05, rho = 0.2, tnum = 5000)
plot(pp1)

plot_power_curve  

Examine a power curve (result function)

Description

This will give a plot of power vs. MDES or sample size. It can be useful to see how quickly power changes as a function of these design parameters. Can be useful to diagnose relatively flat power curves, where power changes little as a function of MDES or sample size, and can also be useful to gauge where convergence went poorly.
plot_power_curve

Usage

plot_power_curve(
  pwr,
  plot.points = TRUE,
  all = TRUE,
  low = NULL,
  high = NULL,
  grid.size = 5,
  tnum = 2000,
  breaks = grid.size,
  fit = NULL
)

Arguments

pwr          pumpresult object or data.frame; result from calling pump_sample or pump_mdes (or data frame from, e.g., power_curve()).
plot.points  logical; whether to plot individually tested points on curve.
all          logical; if TRUE, merge in the search path from the original search.
low          scalar; low range for the plot x-axis.
high         scalar; high range for the plot.
grid.size    scalar; number of points to calculate power.
tnum         scalar; number of iterations to calculate power at each grid point.
breaks       scalar; the desired number of tick marks on the axes.
fit          a four parameter bounded logistic curve (if NULL will fit one to passed points).

Value

plot; a ggplot object of power across values.

Examples

mdes <- pump_mdes(d_m = "d2.1_m2fc", MTP = 'HO',
                  power.definition = 'D1indiv', target.power = 0.7,
                  J = 60, nbar = 50, M = 3, Tbar = 0.5, alpha = 0.05,
                  numCovar.1 = 1, R2.1 = 0.1, ICC.2 = 0.05, rho = 0.2)
plot_power_curve(mdes)
**plot_power_search**

Examine search path of a power search (result function)

**Description**

This will give triple-plots about how the search narrowed down into the final estimate. Can be useful to gauge where convergence went poorly.

**Usage**

```r
plot_power_search(pwr, fit = NULL, target.line = NULL)
```

**Arguments**

- `pwr`: pumpresult object; result from a pump_sample or pump_mdes call.
- `fit`: a fitted curve to the search.
- `target.line`: scalar; if non-NULL, add a reference line for the true power (if known, e.g., from a pump_power call).

**Value**

plot; a ggplot object (a ggpubr arrangement of 3 plots, technically) of the search path.

**Examples**

```r
J <- pump_sample(d_m = "d2.1_m2fc",
                 MTP = 'HO',
                 power.definition = 'D1indiv',
                 typesample = 'J',
                 target.power = 0.6,
                 nbar = 50, M = 3, MDES = 0.125,
                 Tbar = 0.5, alpha = 0.05,
                 numCovar.1 = 1, R2.1 = 0.1, ICC.2 = 0.05,
                 rho = 0.2, tnum = 1000)
plot_power_search(J)
```

---

**power_curve**

Obtain power curve over a range of parameters (result function)

**Description**

This is used to see rate of power change as a function of sample size or MDES.
Usage

```r
power_curve(
  x,
  all = FALSE,
  low = NULL,
  high = NULL,
  grid.size = 5,
  tnum = 2000
)
```

Arguments

- `x`: a pumpresult object.
- `all`: logical; if TRUE, merge in the search path from the original search.
- `low`: scalar; low range for the plot x-axis.
- `high`: scalar; high range for the plot.
- `grid.size`: scalar; number of points to calculate power.
- `tnum`: scalar; number of iterations to calculate power at each grid point.

Value

data.frame of power results.

---

**print_context**  
*Print context (design, model, parameter values) of pumpresult or pumpgridresult*

Description

Print out the context (design and model, with parameter values) of given pump result or pump grid result object. The "***" denotes varying values in the printout.

Usage

```r
print_context(x, insert_results = FALSE, insert_control = FALSE, ...)
```

Arguments

- `x`: A pumpresult object or pumpgridresult object.
- `insert_results`: Include actual results in the printout.
- `insert_control`: Include the optimizer control parameter information.
- ...: Extra arguments to pass to print.pumpresult.

Value

No return value; prints results.
**print_search**

*Print the search history of a pump result object (result function)*

**Description**

For pump_mdes and pump_sample, print the (abbreviated) search history.

**Usage**

```r
print_search(x, n = 10)
```

**Arguments**

- `x`: a pumpresult object (except for is.pumpresult, where it is a generic object to check).
- `n`: Number of lines of search path to print, max.

**Value**

No return value; prints results.

---

**PUMP**

*PUMP: A package for estimating power under multiplicity*

**Description**

The PUMP package provides three core functions:

- `pump_power()` for estimating power
- `pump_mdes()` for estimating minimum detectable effect size
- `pump_sample()` for estimating sample size.

**Details**

pumpgridresult

Result object for results of grid power calculations

Description

The pumpgridresult object is an S3 class that holds the results from 'pump_power_grid()', 'pump_sample_grid()', and 'pump_mdes_grid()'.

It has several methods that pull different information from this object, and some printing methods for getting nicely formatted results.

Usage

is.pumpgridresult(x)

## S3 method for class 'pumpgridresult'
print(x, header = TRUE, ...)

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

Arguments

x a pumpgridresult object (except for is.pumpgridresult, where it is a generic object to check).

header logical; FALSE means skip some header info on the result, just print the data.frame of actual results.

... extra options passed to print.pumpgridresult

object object to summarize.

Value

is.pumpgridresult: TRUE if object is a pumpgridresult object.

print: No return value; prints results.

summary: No return value; prints results.
The `pumpresult` object is an S3 class that holds the results from `pump_power()`, `pump_sample()`, and `pump_mdes()`. It has several methods that pull different information from this object, and some printing methods for getting nicely formatted results.

Pump result objects are also data.frames, so they can be easily manipulated and combined. The return values from the 'grid' functions will just return data frames in general.

Returns whether call was power, mdes, or sample.

Calls the print_context method with results and control both set to TRUE.

Usage

```r
params(x, ...)
d_m(x, ...)
search_path(x, ...)
pump_type(x)
is.pumpresult(x)
```

```r
## S3 method for class 'pumpresult'
x[...]  # S3 method for class 'pumpresult'
x[[...]]  # S3 method for class 'pumpresult'
dim(x, ...)

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

## S3 method for class 'pumpresult'
print(x, n = 10, header = TRUE, search = FALSE, ...)

## S3 method for class 'pumpresult'
as.data.frame(x, row.names = NULL, optional = FALSE, ...)
```
Arguments

- **x**: a pumpresult object (except for is.pumpresult, where it is a generic object to check).
- **...**: additional arguments to be passed to the as.data.frame.list methods.
- **object**: Object to summarize.
- **n**: Number of lines of search path to print, max.
- **header**: FALSE means skip some header info on the result, just print the data.frame of actual results.
- **search**: FALSE means don’t print the search path for a result for mdes or sample.
- **row.names**: NULL or a character vector giving the row names for the data frame.
- **optional**: logical. If TRUE, setting row names and converting column names is optional.

Value

- **params**: List of design parameters used.
- **d_m**: Context (d_m) used (as string).
- **search_path**: Dataframe describing search path, if it was saved in the pumpresult object.
- **pump_type**: power, mdes, or sample, as a string.
- **is.pumpresult**: TRUE if object is a pumpresult object.
- ‘[]’: pull out rows and columns of the dataframe.
- ‘[[]]’: pull out single element of dataframe.
- **dim**: Dimension of pumpresult (as matrix)
- **summary**: No return value; prints results.
- **print**: No return value; prints results.
- **as.data.frame**: pumpresult object as a clean dataframe (no more attributes from pumpresult).

See Also

- update
- update_grid
- print_context
- print_context

Examples

```r/pp <- pump_power(d_m = "d3.2_m3ff2rc",
    MTP = 'HO', nbar = 50, J = 30, K = 10,
    M = 5, MDES = 0.125, Tbar = 0.5, alpha = 0.05,
    numCovar.1 = 1, numCovar.2 = 1,
    R2.1 = 0.1, R2.2 = 0.1, ICC.2 = 0.2, ICC.3 = 0.2,
    omega.2 = 0, omega.3 = 0.1, rho = 0.5, tnum = 1000)

print(pp)
```

pump_info

Provides details about supported package features (core function)

Description

List user options: designs and models (d_m), including what parameters are relevant for each context; multiple testing procedures; types of power; design and model parameters.

Usage

pump_info(
  topic = c("all", "context", "adjustment", "power", "parameters"),
  comment = TRUE
)

Arguments

  topic string; what kind of info. One of: all, context, adjustment, power, parameters.
  comment logical; prints out long description of each design and method.

Value

list; a list of data frames with information about each topic.

See Also

For more detailed information about user choices, see the manuscript https://arxiv.org/abs/2112.15273, which includes a detailed Technical Appendix including information about the designs and models and parameters.
Estimate the minimum detectable effect size (MDES) (core function)

Description

The user chooses the context (d_m), MTP, power definition, and choices of all relevant design parameters.

The functions performs a search algorithm, and returns the MDES value within the specified tolerance. For a list of choices for specific parameters, see pump_info().

Usage

pump_mdes(
  d_m,
  MTP = NULL,
  numZero = NULL,
  M,
  nbar,
  J,
  K = 1,
  Tbar,
  alpha = 0.05,
  two.tailed = TRUE,
  target.power,
  power.definition,
  tol = 0.01,
  numCovar.1 = 0,
  numCovar.2 = 0,
  numCovar.3 = 0,
  R2.1 = 0,
  R2.2 = 0,
  R2.3 = 0,
  ICC.2 = 0,
  ICC.3 = 0,
  omega.2 = 0,
  omega.3 = 0,
  rho = NULL,
  rho.matrix = NULL,
  B = 1000,
  max.steps = 20,
  tnum = 1000,
  start.tnum = tnum/10,
  final.tnum = 4 * tnum,
  parallel.WY.cores = 1,
  updateProgress = NULL,
  give.optimizer.warnings = FALSE,
verbose = FALSE
)

Arguments

d_m string; a single context, which is a design and model code. See `pump_info()` for list of choices.

MTP string, or vector of strings; multiple testing procedure(s). See `pump_info()` for list of choices.

numZero scalar; additional number of outcomes assumed to be zero. Please provide NumZero + length(MDES) = M.

M scalar; the number of hypothesis tests (outcomes), including zero outcomes.

nbar scalar; the harmonic mean of the number of level 1 units per level 2 unit (students per school). Note that this is not the total number of level 1 units, but instead the number of level 1 units nested within each level 2 unit, so the total number of level 1 units is nbar x J x K.

J scalar; the harmonic mean of number of level 2 units per level 3 unit (schools per district). Note that this is not the total number of level 2 units, but instead the number of level 2 units nested within each level 3 unit, so the total number of level 2 units is J x K.

K scalar; the number of level 3 units (districts).

Tbar scalar; the proportion of samples that are assigned to the treatment.

alpha scalar; the family wise error rate (FWER).

two.tailed scalar; TRUE/FALSE for two-tailed or one-tailed power calculation.

target.power target power for search algorithm.

power.definition see `pump_info()` for possible power definitions.

tol tolerance for target power, defaults to 0.01 (1 This parameter controls when the search is done: when estimated power (checked with ‘final.tnum’ iterations) is within ‘tol’, the search stops.

numCovar.1 scalar; number of level 1 (individual) covariates.

numCovar.2 scalar; number of level 2 (school) covariates.

numCovar.3 scalar; number of level 3 (district) covariates.

R2.1 scalar, or vector of length M; percent of variation explained by level 1 covariates for each outcome.

R2.2 scalar, or vector of length M; percent of variation explained by level 2 covariates for each outcome.

R2.3 scalar, or vector of length M; percent of variation explained by level 3 covariates for each outcome.

ICC.2 scalar, or vector of length M; level 2 (school) intraclass correlation.

ICC.3 scalar, or vector length M; level 3 (district) intraclass correlation.

omega.2 scalar, or vector of length M; ratio of variance of level 2 average impacts to variance of level 2 random intercepts.
omega.3 scalar, or vector of length M; ratio of variance of level 3 average impacts to variance of level 3 random intercepts.
rho scalar; assumed correlation between all pairs of test statistics.
rho.matrix matrix; alternate specification allowing a full matrix of correlations between test statistics. Must specify either rho or rho.matrix, but not both.
B scalar; the number of permutations for Westfall-Young procedures.
max.steps how many steps allowed before terminating.
tnum max number of samples for first iteration of search algorithm.
start.tnum number of samples to start search (this will increase with each step).
final.tnum number of samples for final draw.
parallel.WY.cores number of cores to use for parallel processing of WY-SD.
updateProgress function to update progress bar (only used for PUMP shiny app).
give.optimizer.warnings whether to return verbose optimizer warnings.
verbose TRUE/FALSE; Print out diagnostics of time, etc.

Value

a pumpresult object containing MDES results.

See Also

For more detailed information about this function and the user choices, see the manuscript https://arxiv.org/abs/2112.15273, which includes a detailed Technical Appendix including information about the designs and models and parameters.

Examples

mdes <- pump_mdes(
  d_m = "d3.1_m3rr2rr",
  MTP = 'HO',
  power.definition = 'D1indiv',
  target.power = 0.6,
  J = 30,
  K = 15,
  nbar = 50,
  M = 3,
  Tbar = 0.5, alpha = 0.05,
  two.tailed = FALSE,
  numCovar.1 = 1, numCovar.2 = 1,
  R2.1 = 0.1, R2.2 = 0.1,
  ICC.2 = 0.2, ICC.3 = 0.2,
  omega.2 = 0.1, omega.3 = 0.1,
  rho = 0.5, tnum = 2000)
Run `pump_mdes` on varying values of parameters (grid function)  

Description

See `pump_power_grid()` for more details.

Usage

```r
pump_mdes_grid(
  d_m,  # string; a single context, which is a design and model code. See pump_info() for list of choices.
  MTP,  # string, or vector of strings; multiple testing procedure(s). See pump_info() for list of choices.
  M,  # scalar; the number of hypothesis tests (outcomes), including zero outcomes.
  target.power,  # target power for search algorithm.
  power.definition,  #
  tol = 0.01,  #
  nbar,  #
  J = 1,  #
  K = 1,  #
  Tbar,  #
  alpha,  #
  numCovar.1 = NULL,  #
  numCovar.2 = NULL,  #
  numCovar.3 = NULL,  #
  R2.1 = NULL,  #
  R2.2 = NULL,  #
  R2.3 = NULL,  #
  ICC.2 = NULL,  #
  ICC.3 = NULL,  #
  omega.2 = NULL,  #
  omega.3 = NULL,  #
  rho,  #
  verbose = FALSE,  #
  drop.unique.columns = TRUE,  #
  ...  
)
```

Arguments

d_m  
MTP  
M  
target.power
power.definition

see pump_info() for possible power definitions.

tol

tolerance for target power, defaults to 0.01 (1 This parameter controls when the search is done: when estimated power (checked with ‘final.tnum’ iterations) is within ‘tol’, the search stops.

nbar

scalar; the harmonic mean of the number of level 1 units per level 2 unit (students per school). Note that this is not the total number of level 1 units, but instead the number of level 1 units nested within each level 2 unit, so the total number of level 1 units is nbar x J x K.

J

scalar; the harmonic mean of number of level 2 units per level 3 unit (schools per district). Note that this is not the total number of level 2 units, but instead the number of level 2 units nested within each level 3 unit, so the total number of level 2 units is J x K.

K

scalar; the number of level 3 units (districts).

Tbar

scalar; the proportion of samples that are assigned to the treatment.

alpha

scalar; the family wise error rate (FWER).

numCovar.1

scalar; number of level 1 (individual) covariates.

numCovar.2

scalar; number of level 2 (school) covariates.

numCovar.3

scalar; number of level 3 (district) covariates.

R2.1

scalar, or vector of length M; percent of variation explained by level 1 covariates for each outcome.

R2.2

scalar, or vector of length M; percent of variation explained by level 2 covariates for each outcome.

R2.3

scalar, or vector of length M; percent of variation explained by level 3 covariates for each outcome.

ICC.2

scalar, or vector of length M; level 2 (school) intraclass correlation.

ICC.3

scalar, or vector length M; level 3 (district) intraclass correlation.

omega.2

scalar, or vector of length M; ratio of variance of level 2 average impacts to variance of level 2 random intercepts.

omega.3

scalar, or vector of length M; ratio of variance of level 3 average impacts to variance of level 3 random intercepts.

rho

scalar; assumed correlation between all pairs of test statistics.

verbose

TRUE/FALSE; Print out diagnostics of time, etc.

drop.unique.columns

logical; drop all parameter columns that did not vary across the grid.

...

extra arguments passed to the underlying pump_power, pump_sample, or pump_mdes functions.

Value

a pumpgridresult object containing MDES results.
See Also

Other grid functions: `pump_power_grid()`, `pump_sample_grid()`

Examples

g <- pump_mdes_grid(d_m = "d3.2_m3ff2rc", MTP = "HO",
target.power = c( 0.50, 0.80 ), power.definition = "D1indiv",
tol = 0.05, M = 5, J = c( 3, 9), K = 7, nbar = 58,
Tbar = 0.50, alpha = 0.15, numCovar.1 = 1, numCovar.2 = 1,
R2.1 = 0.1, R2.2 = 0.7, ICC.2 = 0.05, ICC.3 = 0.9,
rho = 0.4, tnum = 500)

Description

The user chooses the context (d_m), MTP, MDES, and choices of all relevant design parameters.
The functions returns power for all definitions of power for any MTP. For a list of choices for specific parameters, see `pump_info()`.

Usage

```r
pump_power(
  d_m,
  MTP = NULL,
  MDES,
  numZero = NULL,
  M,
  nbar,
  J = 1,
  K = 1,
  Tbar,
  alpha = 0.05,
  two.tailed = TRUE,
  numCovar.1 = 0,
  numCovar.2 = 0,
  numCovar.3 = 0,
  R2.1 = 0,
  R2.2 = 0,
  R2.3 = 0,
  ICC.2 = 0,
  ICC.3 = 0,
  omega.2 = 0,
  omega.3 = 0,
  rho = NULL,
  rho.matrix = NULL,
```
pump_power

tnum = 10000,
B = 1000,
parallel.WY.cores = 1,
drop.zero.outcomes = TRUE,
updateProgress = NULL,
validate.inputs = TRUE,
long.table = FALSE,
verbose = FALSE
)

Arguments

d_m string; a single context, which is a design and model code. See pump_info() for list of choices.
MTP string, or vector of strings; multiple testing procedure(s). See pump_info() for list of choices.
MDES scalar or vector; the desired MDES values for each outcome. Please provide a scalar, a vector of length M, or vector of values for non-zero outcomes.
umZero scalar; additional number of outcomes assumed to be zero. Please provide NumZero + length(MDES) = M.
M scalar; the number of hypothesis tests (outcomes), including zero outcomes.
nbar scalar; the harmonic mean of the number of level 1 units per level 2 unit (students per school). Note that this is not the total number of level 1 units, but instead the number of level 1 units nested within each level 2 unit, so the total number of level 1 units is nbar x J x K.
J scalar; the harmonic mean of number of level 2 units per level 3 unit (schools per district). Note that this is not the total number of level 2 units, but instead the number of level 2 units nested within each level 3 unit, so the total number of level 2 units is J x K.
K scalar; the number of level 3 units (districts).
Tbar scalar; the proportion of samples that are assigned to the treatment.
alpha scalar; the family wise error rate (FWER).
two.tailed scalar; TRUE/FALSE for two-tailed or one-tailed power calculation.
umCovar.1 scalar; number of level 1 (individual) covariates.
umCovar.2 scalar; number of level 2 (school) covariates.
umCovar.3 scalar; number of level 3 (district) covariates.
R2.1 scalar, or vector of length M; percent of variation explained by level 1 covariates for each outcome.
R2.2 scalar, or vector of length M; percent of variation explained by level 2 covariates for each outcome.
R2.3 scalar, or vector of length M; percent of variation explained by level 3 covariates for each outcome.
ICC.2 scalar, or vector of length M; level 2 (school) intraclass correlation.
pump_power

ICC.3 scalar, or vector length M; level 3 (district) intraclass correlation.

omega.2 scalar, or vector of length M; ratio of variance of level 2 average impacts to variance of level 2 random intercepts.

omega.3 scalar, or vector of length M; ratio of variance of level 3 average impacts to variance of level 3 random intercepts.

rho scalar; assumed correlation between all pairs of test statistics.

rho.matrix matrix; alternate specification allowing a full matrix of correlations between test statistics. Must specify either rho or rho.matrix, but not both.

tnum scalar; the number of test statistics to draw. Increasing tnum increases precision and computation time.

B scalar; the number of permutations for Westfall-Young procedures.

parallel.WY.cores number of cores to use for parallel processing of WY-SD.

donzero.outcomes whether to report power results for outcomes with MDES = 0.

updateProgress function to update progress bar (only used for PUMP shiny app).

validate.inputs TRUE/FALSE; whether or not to check whether parameters are valid given the choice of d_m.

long.table TRUE for table with power as rows, correction as columns, and with more verbose names. See 'transpose_power_table'.

verbose TRUE/FALSE; Print out diagnostics of time, etc.

Value

a pumpreresult object containing power results.

See Also

For more detailed information about this function and the user choices, see the manuscript https://arxiv.org/abs/2112.15273, which includes a detailed Technical Appendix including information about the designs and models and parameters.

Examples

pp <- pump_power(
  d_m = "d3.2_m3ff2rc",
  MTP = 'HO',
  nbar = 50,
  J = 30,
  K = 10,
  M = 5,
  MDES = 0.125,
  Tbar = 0.5, alpha = 0.05,
  numCovar.1 = 1, numCovar.2 = 1,
  R2.1 = 0.1, R2.2 = 0.1,
  ICC.2 = 0.2, ICC.3 = 0.2,
pump_power_grid  

Run pump_power on varying values of parameters (grid function)

Description

This extension of 'pump_power()' will take lists of parameter values and run 'pump_power()' on all combinations of these values.

It can only assume the same MDES value for all outcomes due to this. (I.e., a vector of MDES values will be interpreted as a sequence of calls to pump_power, one for each MDES value given).

Each parameter in the parameter list can be a list, not scalar. It will cross all combinations of the list.

Usage

pump_power_grid(
  d_m,
  MTP,
  MDES,
  M,
  nbar,
  J = 1,
  K = 1,
  numZero = NULL,
  Tbar,
  alpha = 0.05,
  numCovar.1 = NULL,
  numCovar.2 = NULL,
  numCovar.3 = NULL,
  R2.1 = NULL,
  R2.2 = NULL,
  R2.3 = NULL,
  ICC.2 = NULL,
  ICC.3 = NULL,
  omega.2 = NULL,
  omega.3 = NULL,
  rho,
  long.table = FALSE,
  verbose = FALSE,
  drop.unique.columns = TRUE,
  ...
)

omega.2 = 0, omega.3 = 0.1,
rho = 0.5)
Arguments

d_m
string; a single context, which is a design and model code. See pump_info() for list of choices.

MTP
string, or vector of strings; multiple testing procedure(s). See pump_info() for list of choices.

MDES
vector of numeric; This is *not* a list of MDES for each outcome, but rather a list of MDES to explore. Each value will be assumed held constant across all M outcomes.

M
scalar; the number of hypothesis tests (outcomes), including zero outcomes.

nbar
scalar; the harmonic mean of the number of level 1 units per level 2 unit (students per school). Note that this is not the total number of level 1 units, but instead the number of level 1 units nested within each level 2 unit, so the total number of level 1 units is nbar x J x K.

J
scalar; the harmonic mean of number of level 2 units per level 3 unit (schools per district). Note that this is not the total number of level 2 units, but instead the number of level 2 units nested within each level 3 unit, so the total number of level 2 units is J x K.

K
scalar; the number of level 3 units (districts).

numZero
scalar; additional number of outcomes assumed to be zero. Please provide NumZero + length(MDES) = M.

Tbar
scalar; the proportion of samples that are assigned to the treatment.

alpha
scalar; the family wise error rate (FWER).

numCovar.1
scalar; number of level 1 (individual) covariates.

numCovar.2
scalar; number of level 2 (school) covariates.

numCovar.3
scalar; number of level 3 (district) covariates.

R2.1
scalar, or vector of length M; percent of variation explained by level 1 covariates for each outcome.

R2.2
scalar, or vector of length M; percent of variation explained by level 2 covariates for each outcome.

R2.3
scalar, or vector of length M; percent of variation explained by level 3 covariates for each outcome.

ICC.2
scalar, or vector of length M; level 2 (school) intraclass correlation.

ICC.3
scalar, or vector length M; level 3 (district) intraclass correlation.

omega.2
scalar, or vector of length M; ratio of variance of level 2 average impacts to variance of level 2 random intercepts.

omega.3
scalar, or vector of length M; ratio of variance of level 3 average impacts to variance of level 3 random intercepts.

rho
scalar; assumed correlation between all pairs of test statistics.

long.table
TRUE for table with power as rows, correction as columns, and with more verbose names. See ‘transpose_power_table’.

verbose
logical; TRUE means print out some text as calls processed. FALSE do not.
drop.unique.columns

logical; drop all parameter columns that did not vary across the grid.

... extra arguments passed to the underlying pump_power, pump_sample, or pump_mdes functions.

Value

a pumpgridresult object containing power results.

See Also

Other grid functions: pump_mdes_grid(), pump_sample_grid()

Examples

g <- pump_power_grid(d_m = "d3.2_m3ff2rc", MTP = c("HO", "BF"),
MDES = 0.10, J = seq(5, 10, 1), M = 5, K = 7, nbar = 58,
Tbar = 0.50, alpha = 0.15, numCovar.1 = 1,
numCovar.2 = 1, R2.1 = 0.1, R2.2 = 0.7,
ICC.2 = 0.25, ICC.3 = 0.25, rho = 0.4, tnum = 1000)

pump_sample                 Estimate the required sample size (core function)

Description

The user chooses the context (d_m), MTP, type of sample size, MDES, power definition, and choices of all relevant design parameters.

The functions performs a search algorithm, and returns the sample size value within the specified tolerance. For a list of choices for specific parameters, see pump_info().

Usage

pump_sample(
  d_m,
  MTP = NULL,
  typesample,
  MDES,
  M,
  numZero = NULL,
  nbar = NULL,
  J = NULL,
  K = NULL,
  target.power,
  power.definition,
  alpha,
  two.tailed = TRUE,
  Tbar,
numCovar.1 = 0,  
numCovar.2 = 0,  
numCovar.3 = 0,  
R2.1 = 0,  
R2.2 = 0,  
R2.3 = 0,  
ICC.2 = 0,  
ICC.3 = 0,  
rho = NULL,  
rho.matrix = NULL,  
omega.2 = 0,  
omega.3 = 0,  
B = 1000,  
max.steps = 20,  
tnum = 1000,  
start.tnum = tnum/10,  
final.tnum = 4 * tnum,  
parallel.WY.cores = 1,  
updateProgress = NULL,  
max_sample_size_nbar = 10000,  
max_sample_size_JK = 1000,  
tol = 0.01,  
give.optimizer.warnings = FALSE,  
verbose = FALSE
)

Arguments

d_m 
string: a single context, which is a design and model code. See pump_info() for list of choices.

MTP 
string, or vector of strings; multiple testing procedure(s). See pump_info() for list of choices.

typesample 
string: type of sample size to calculate: "nbar", "J", or "K".

MDES 
scalar or vector; the desired MDES values for each outcome. Please provide a scalar, a vector of length M, or vector of values for non-zero outcomes.

M 
scalar; the number of hypothesis tests (outcomes), including zero outcomes.

numZero 
scalar; additional number of outcomes assumed to be zero. Please provide NumZero + length(MDES) = M.

nbar 
scalar; the harmonic mean of the number of level 1 units per level 2 unit (students per school). Note that this is not the total number of level 1 units, but instead the number of level 1 units nested within each level 2 unit, so the total number of level 1 units is nbar x J x K.

J 
scalar; the harmonic mean of number of level 2 units per level 3 unit (schools per district). Note that this is not the total number of level 2 units, but instead the number of level 2 units nested within each level 3 unit, so the total number of level 2 units is J x K.
K  scalar; the number of level 3 units (districts).
target.power  target power for search algorithm.

power.definition  see pump_info() for possible power definitions.
alpha  scalar; the family wise error rate (FWER).
two.tailed  scalar; TRUE/FALSE for two-tailed or one-tailed power calculation.
Tbar  scalar; the proportion of samples that are assigned to the treatment.
numCovar.1  scalar; number of level 1 (individual) covariates.
numCovar.2  scalar; number of level 2 (school) covariates.
numCovar.3  scalar; number of level 3 (district) covariates.
R2.1  scalar, or vector of length M; percent of variation explained by level 1 covariates for each outcome.
R2.2  scalar, or vector of length M; percent of variation explained by level 2 covariates for each outcome.
R2.3  scalar, or vector of length M; percent of variation explained by level 3 covariates for each outcome.
ICC.2  scalar, or vector of length M; level 2 (school) intraclass correlation.
ICC.3  scalar, or vector of length M; level 3 (district) intraclass correlation.
rho  scalar; assumed correlation between all pairs of test statistics.
rho.matrix  matrix; alternate specification allowing a full matrix of correlations between test statistics. Must specify either rho or rho.matrix, but not both.
omega.2  scalar, or vector of length M; ratio of variance of level 2 average impacts to variance of level 2 random intercepts.
omega.3  scalar, or vector of length M; ratio of variance of level 3 average impacts to variance of level 3 random intercepts.
B  scalar; the number of permutations for Westfall-Young procedures.
max.steps  how many steps allowed before terminating.
tnum  max number of samples for first iteration of search algorithm.
start.tnum  number of samples to start search (this will increase with each step).
final.tnum  number of samples for final draw.
parallel.WY.cores  number of cores to use for parallel processing of WY-SD.
updateProgress  function to update progress bar (only used for PUMP shiny app).
max_sample_size_nbar  scalar; default upper bound for nbar for search algorithm.
max_sample_size_JK  scalar; default upper bound for J or K for search algorithm.
tol  tolerance for target power, defaults to 0.01 (1 This parameter controls when the search is done: when estimated power (checked with ‘final.tnum’ iterations) is within ‘tol’, the search stops.
give.optimizer.warnings  whether to return verbose optimizer warnings.
verbose  TRUE/FALSE; Print out diagnostics of time, etc.
Value

a pumpresult object containing sample size results.

See Also

For more detailed information about this function and the user choices, see the manuscript https://arxiv.org/abs/2112.15273, which includes a detailed Technical Appendix including information about the designs and models and parameters.

Examples

```r
J <- pump_sample(
  d_m = 'd2.1_m2fc',
  MTP = 'HO',
  power.definition = 'D1indiv',
  typesample = 'J',
  target.power = 0.8,
  nbar = 50,
  M = 3,
  MDES = 0.125,
  Tbar = 0.5, alpha = 0.05,
  numCovar.1 = 1,
  R2.1 = 0.1, ICC.2 = 0.05, rho = 0.2,
  tnum = 1000)
```

```
pump_sample_grid  Run pump_sample on varying values of parameters (grid function)
```

Description

See pump_power_grid() for further details.

Usage

```r
pump_sample_grid(
  d_m, MTP, M, target.power, power.definition, tol = 0.01,
  MDES = NULL, typesample, nbar = NULL, J = NULL, K = NULL, Tbar, alpha,
```
pump_sample_grid

numCovar.1 = NULL,
numCovar.2 = NULL,
numCovar.3 = NULL,
R2.1 = NULL,
R2.2 = NULL,
R2.3 = NULL,
ICC.2 = NULL,
ICC.3 = NULL,
omega.2 = NULL,
omega.3 = NULL,
rho,
verbose = FALSE,
drop.unique.columns = TRUE,
}

Arguments

d_m string; a single context, which is a design and model code. See pump_info() for list of choices.

MTP string, or vector of strings; multiple testing procedure(s). See pump_info() for list of choices.

M scalar; the number of hypothesis tests (outcomes), including zero outcomes.
target.power target power for search algorithm.
power.definition see pump_info() for possible power definitions.
tol tolerance for target power, defaults to 0.01 (1 This parameter controls when the search is done: when estimated power (checked with `final.tnum` iterations) is within `tol`, the search stops.

MDES scalar or vector; the desired MDES values for each outcome. Please provide a scalar, a vector of length M, or vector of values for non-zero outcomes.
typesample string; type of sample size to calculate: "nbar", "J", or "K".
nbar scalar; the harmonic mean of the number of level 1 units per level 2 unit (students per school). Note that this is not the total number of level 1 units, but instead the number of level 1 units nested within each level 2 unit, so the total number of level 1 units is nbar x J x K.

J scalar; the harmonic mean of number of level 2 units per level 3 unit (schools per district). Note that this is not the total number of level 2 units, but instead the number of level 2 units nested within each level 3 unit, so the total number of level 2 units is J x K.

K scalar; the number of level 3 units (districts).

Tbar scalar; the proportion of samples that are assigned to the treatment.

alpha scalar; the family wise error rate (FWER).

numCovar.1 scalar; number of level 1 (individual) covariates.

numCovar.2 scalar; number of level 2 (school) covariates.
numCovar.3  scalar; number of level 3 (district) covariates.
R2.1   scalar, or vector of length M; percent of variation explained by level 1 covariates for each outcome.
R2.2   scalar, or vector of length M; percent of variation explained by level 2 covariates for each outcome.
R2.3   scalar, or vector of length M; percent of variation explained by level 3 covariates for each outcome.
ICC.2   scalar, or vector of length M; level 2 (school) intraclass correlation.
ICC.3   scalar, or vector length M; level 3 (district) intraclass correlation.
omega.2  scalar, or vector of length M; ratio of variance of level 2 average impacts to variance of level 2 random intercepts.
omega.3  scalar, or vector of length M; ratio of variance of level 3 average impacts to variance of level 3 random intercepts.
rho    scalar; assumed correlation between all pairs of test statistics.
verbose    TRUE/FALSE; Print out diagnostics of time, etc.
drop.unique.columns    logical; drop all parameter columns that did not vary across the grid.
...
... extra arguments passed to the underlying pump_power, pump_sample, or pump_mdes functions.

Value

a pumpgridresult object containing sample results.

See Also

Other grid functions: pump_mdes_grid(), pump_power_grid()

Examples

g <- pump_sample_grid(d_m = "d3.2_m3ff2rc", typesample = "J", MTP = "HO", MDES = 0.10, target.power = c(0.50, 0.80), power.definition = "min1", tol = 0.03, M = 5, K = 7, nbar = 58, Tbar = 0.50, alpha = 0.15, numCovar.1 = 1, numCovar.2 = 1, R2.1 = 0.1, R2.2 = 0.7, ICC.2 = 0.25, ICC.3 = 0.25, rho = 0.4, tnum = 400)
transpose_power_table  Convert power table from wide to long (result function)

Description
Transform table returned from pump_power to a long format table or to a wide format table.

Usage
transpose_power_table(power_table, M = NULL)

Arguments
- power_table: pumpresult object for a power result (not mdes or sample). (It can also take a raw dataframe of the wide table to convert to long, as an internal helper method.)
- M: scalar; set if power_table is a data.frame without set number of outcomes. Usually ignore this.

Value
data.frame of power results in long format.

update.pumpresult  Update a pump call, tweaking some parameters (core function)

Description
Works on objects returned by pump_power(), pump_mdes(), or pump_sample(). One of the optional parameters can be a 'type = something' argument, where the 'something' is either "power", "sample", or "mdes", if the call should be shifted to a different pump call (pump_power, pump_sample, or pump_mdes, respectively).

Usage
## S3 method for class 'pumpresult'
update(object, type = NULL, ...)

Arguments
- object: pump result object.
- type: string; can be "power", "mdes" or "sample", sets the type of the updated call (can be different from original).
- ...: parameters as specified in 'pump_power', 'pump_mdes', and 'pump_sample' that should be overwritten.
Value

a pumpresult object: results of a new call using parameters of old object with newly specified parameters replaced.

Examples

```r
ss <- pump_sample( d_m = "d2.1_m2fc", MTP = "HO", typesample = "J", nbar = 200, power.definition = "min!", M = 5, MDES = 0.05, target.power = 0.5, tol = 0.05, Tbar = 0.50, alpha = 0.05, numCovar.1 = 5, R2.1 = 0.1, ICC.2 = 0.15, rho = 0, final.tnum = 1000 )

up <- update(ss, nbar = 40, tnum = 2000 )
```

update_grid

Update a single pump call to a grid call (grid function)

Description

Take a pumpresult and provide lists of parameters to explore various versions of the initial scenario.

Usage

```r
update_grid(x, ...)
```

Arguments

- **x**
  - pump result object.
- **...**
  - list of parameters to expand into a grid.

Value

a pumpgridresult object; result of calling corresponding grid.

Examples

```r
pp <- pump_power(d_m = "d2.1_m2fc", MTP = "HO", nbar = 200, J = 20, MDES = 0.2, M = 3, Tbar = 0.50, alpha = 0.05, numCovar.1 = 5, R2.1 = 0.1, ICC.2 = 0.05, rho = 0, tnum = 500)

gd <- update_grid( pp, J = c( 10, 20, 30 ) )
```
Index

* grid functions
  pump_mdes_grid, 21
  pump_power_grid, 26
  pump_sample_grid, 31

* pump_info
  parse_d_m, 7
  [.pumpresult(pumpresult), 15
  [[.pumpresult(pumpresult), 15
  as.data.frame.pumpresult(pumpresult), 15

  calc_df, 2
  convert_params, 3

  d_m(pumpresult), 15
  dim.pumpresult(pumpresult), 15

  gen_assignments, 4
  gen_corr_matrix, 4
  gen_full_data, 5
  gen_T.x, 5
  gen_Yobs, 6
  get_power_results, 6

  is.pumpgridresult(pumpgridresult), 14
  is.pumpresult(pumpresult), 15

  params(pumpresult), 15
  parse_d_m, 7
  plot.pumpgridresult, 8
  plot.pumpresult, 9
  plot_power_curve, 9
  plot_power_search, 11
  power_curve, 11
  print.pumpgridresult(pumpgridresult), 14
  print.pumpresult(pumpresult), 15
  print_context, 12
  print_search, 13
  PUMP, 13

  pump_info, 17
  pump_mdes, 18
  pump_mdes_grid, 21, 28, 33
  pump_power, 23
  pump_power_grid, 23, 26, 33
  pump_sample, 28
  pump_sample_grid, 23, 28, 31
  pump_type(pumpresult), 15
  pumpgridresult, 14
  pumpresult, 15

  search_path(pumpresult), 15
  summary.pumpgridresult
    (pumpgridresult), 14
  summary.pumpresult(pumpresult), 15

  transpose_power_table, 34

  update.pumpresult, 34
  update_grid, 35