Package ‘PUMP’

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**calc_df**  
*Calculate degrees of freedom (support function)*

**Description**

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

**Usage**

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

Arguments

- **d_m**: string; a single context, which is a design and model code. See pump_info() for list of choices.
- **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).
- **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.
- **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.
- **validate**: logical; whether or not to validate if output df is <= 0.

Value

- scalar; degrees of freedom for the context.

---

**Description**

Estimates the pairwise correlations between test statistics for all outcomes.

Takes in two options: - a pumpresult object OR - a list of necessary data-generating parameters - the context (d_m) - Tbar

Note that this function can take several minutes to run.

**Usage**

```r
check_cor(
pump.object = NULL,
rho.V = NULL,
rho.w0 = NULL,
rho.w1 = NULL,
rho.X = NULL,
rho.u0 = NULL,
rho.u1 = NULL,
rho.C = NULL,
rho.r = NULL,
d_m = NULL,
)```

model.params.list = NULL,
Tbar = 0.5,
n.sims = 100
)

Arguments

- **pump.object**: A pumpresult object.
- **rho.V**: matrix; correlation matrix of level 3 covariates.
- **rho.w0**: matrix; correlation matrix of level 3 random effects.
- **rho.w1**: matrix; correlation matrix of level 3 random impacts.
- **rho.X**: matrix; correlation matrix of level 2 covariates.
- **rho.u0**: matrix; correlation matrix of level 2 random effects.
- **rho.u1**: matrix; correlation matrix of level 2 random impacts.
- **rho.C**: matrix; correlation matrix of level 1 covariates.
- **rho.r**: matrix; correlation matrix of level 1 residuals.
- **d_m**: string; a single context, which is a design and model code. See pump_info() for list of choices.
- **model.params.list**: list; model parameters such as ICC, R2, etc. See simulation vignette for details.
- **Tbar**: scalar; the proportion of samples that are assigned to the treatment.
- **n.sims**: numeric; Number of simulated datasets to generate. More datasets will achieve a more accurate result but also increase computation time.

Value

matrix; M x M correlation matrix between test statistics.

Examples

pp <- pump_power(d_m = "d3.2_m3ff2rc",
MTP = "BF",
MDES = rep( 0.10, 2 ),
M = 2,
J = 4, # number of schools/block
K = 10, # number RA blocks
nbar = 50,
Tbar = 0.50, # prop Tx
alpha = 0.05, # significance level
numCovar.1 = 5, numCovar.2 = 3,
R2.1 = 0.1, R2.2 = 0.7,
ICC.2 = 0.05, ICC.3 = 0.4,
rho = 0.4, # how correlated test statistics are
tnum = 200
)
cor.tstat <- check_cor(
  pump.object = pp, n.sims = 4
)
est.cor <- mean(cor.tstat[lower.tri(cor.tstat)])
**convert_params**

*Converts model params into DGP params (simulation function)*

**Description**

Converts user-provided parameters such as ICC and omega into data-generating parameters for the multilevel random effects model used to 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(param.list)
```

**Arguments**

- `param.list`: list; model parameters such as ICC, R2, etc.

**Value**

list; data-generating parameters.

---

**gen_base_sim_data**

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

**Description**

Generates simulated data for multi-level RCTs for pump-supported designs and models for both unobserved potential outcomes. This function does not generate treatment assignments or observed outcomes—see `gen_sim_data()` for that.

This method takes in a list of necessary data-generating parameters, following the rest of the package.

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_base_sim_data(
  param.list,
  pump.object = NULL,
  return.as.dataframe = TRUE,
  no.list = TRUE,
  dgp.params = FALSE
)
```
Arguments

**param.list**
list; model parameters such as ICC, R², etc. See simulation vignette for details.

**pump.object**
A pump.result object.

**return.as.dataframe**
TRUE means return list of dataframes, one for each outcome. FALSE means return components of the covariates, etc., in a list.

**no.list**
Only relevant if return.as.dataframe=TRUE. no.list=TRUE means if M=1 return the dataframe, not a list of length 1. FALSE means return a list of length 1, even if there is only 1 outcome.

**dgp.params**
TRUE means param.list is already converted to DGP parameters, FALSE means it needs to be converted via `convert_params()`.

Value

list; potential outcomes given control y0, treatment y1, covariates V.k, X.jk, C.ijk, or list of dataframes if return.as.dataframe = TRUE.

See Also

gen_sim_data

generate_cluster_ids

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

gen_cluster_ids(nbar, J, K)

Arguments

**nbar**
scalar; number of individuals per school.

**J**
scalar; number of schools per district.

**K**
scalar; number of districts.

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_sim_data

Generate simulated multi-level data (simulation function)

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

Usage
```r
gen_sim_data(
  d_m = NULL,
  param.list = NULL,
  Tbar = 0.5,
  pump.object = NULL,
  return.as.dataframe = TRUE,
  no.list = TRUE
)
```
Arguments

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

param.list list; model parameters such as ICC, R2, etc. See simulation vignette for details.

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

pump.object A pumpresult object.

return.as.dataframe

TRUE means return list of dataframes, one for each outcome. FALSE means
return components of the covariates, etc., in a list.

no.list Only relevant if return.as.dataframe=TRUE. no.list=TRUE means if M=1 return
the dataframe, not a list of length 1. FALSE means return a list of length 1, even
if there is only 1 outcome.

Value

list; potential outcomes, covariates, observed outcomes, and treatment assignment.

Examples

pp <- pump_power( d_m = "d3.2_m3ff2rc",
    MTP = "BF",
    MDES = rep( 0.10, 3 ),
    M = 3,
    J = 3, # number of schools/block
    K = 21, # number RA blocks
    nbar = 258,
    Tbar = 0.50, # prop Tx
    alpha = 0.05, # significance level
    numCovar.1 = 5, numCovar.2 = 3,
    R2.1 = 0.1, R2.2 = 0.7,
    ICC.2 = 0.05, ICC.3 = 0.4,
    rho = 0.4,
    tnum = 200
)

sim.data <- gen_sim_data(pump.object = pp)

---

generate_treatment_vector

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, Tbar)
```

**Arguments**

- `d_m` : string; design and model.
- `S.id` : vector; school assignments.
- `D.id` : vector; district assignments.
- `Tbar` : scalar; probability of treatment assignment.

**Value**

vector; treatment assignments for each unit.

---

**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,  
  unadj.pval.mat,  
  ind.nonzero,  
  alpha,  
  drop.zero.outcomes = TRUE,  
  adj = TRUE
)
```

**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.

### parse_d_m

*Return characteristics of a given context/d_m code (support function)*

**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 pumpgridresult 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
## S3 method for class 'pumpgridresult'
plot(
  x,
  power.definition = NULL,
  var.vary = NULL,
  color = "MTP",
  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.

color string; Group lines by this element to make an interaction plot (default "MTP", giving one curve for each MTP).

groups 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
# S3 method for class 'pumpresult'
plot(
  x,
  type = "power",
  all = TRUE,
  low = NULL,
  high = NULL,
  grid.size = 5,
)
```

plot.pumpresult | Plot a pumpresult object (result function)

Description

For the object returned by pump_power(), visualizes different definitions of power across MTPs. For the object returned by pump_mdes() or pump_sample(), plot a power curve as a function of MDES or sample size, respectively. This latter call will calculate power over a passed range from low to high to generate this curve.

Several of the passed parameters only apply to the mdes or sample versions, and are for controlling the grid search and plot.

For pump_power, will include standard errors of uncertainty on calculated power. These depend on number of iterations (tnum) used in the simulation.
Arguments

x  
pumpresult object.

type  
string: "power" or "search". Specifies whether to plot the default power graph, or the search path. The search path is only valid for MDES and SS results.

all  
Logical. If TRUE, merge in the search path from the original search to the estimated power curve, for MDES or sample plots.

low  
Low range of x-axis and curve calculation for sample or MDES plots. (Optional.)

high  
High range of x-axis and curve calculation. (Optional.)

grid.size  
If calculating curve for sample or MDES plot, how many grid points?

breaks  
If plotting a curve for sample or MDES, where to put the grid points?

include_SE  
Include (approximate) SEs on the power estimates, if they are naturally calculated.

...  
additional parameters, such as, in case of sample or mdes objects, tnum for setting number of replicates or all (logical) for determining whether to include original points in the estimated curve, or include.points (logical) for including points on the plot itself.

Value

plot; a ggplot object of power across different definitions.

Examples

```r
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 = 200)
plot(pp1)

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 = 200)
plot(J)
plot(J, type = "search")
```
Power Curve

Obtain a power curve for a range of sample size or MDES values

Description

This is used to see how power changes as a function of sample size or MDES. It takes a fit pumpreresult and calculates a power curve based on that scenario coupled with a passed range of values to make the curve over.

Usage

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

Arguments

- `x`: a pumpreresult object.
- `all`: logical; if TRUE, merge in the search path from the original search.
- `low`: scalar; low range for curve.
- `high`: scalar; high range for the curve.
- `grid.size`: scalar; number of points to calculate power for.
- `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 pumpreresult or pumpgridresult (result function)

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.

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_mdes_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

```r
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.

pumpresult

*pumpresult* object for results of power calculations

Description

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

- `params(x, ...)`
- `d_m(x, ...)`
- `design(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).
- **design**: (the randomization and levels) 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

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)
params(pp)
print_context(pp)
d_m(pp)
pump_type(pp)
is.powerresult(pp)
as.data.frame(pp)
dim(pp)
summary(pp)
transpose_power_table(pp)

J <- pump_sample(d_m = "d2.1_m2fc",
MTP = 'HO', power.definition = 'D1indiv',
typesample = 'J', target.power = 0.7,
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)

search_path(J)
power_curve(J)
Usage

```r
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](https://arxiv.org/abs/2112.15273), which includes a detailed Technical Appendix including information about the designs and models and parameters.

---

**pump_mdes**

*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

```r
pump_mdes(
  d_m,
  MTP = NULL,
  numZero = NULL,
  propZero = NULL,
  M = 1,
  nbar,
  J = 1,
  K = 1,
  Tbar,
  alpha = 0.05,
  two.tailed = TRUE,
  target.power = 0.8,
)```
power.definition,
tol = 0.02,
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 = round(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, if length(MDES) is not 1.
propZero scalar; proportion of outcomes assumed to be zero (alternative specification to
      numZero). length(MDES) should be 1 or equal to (1-propZero)*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](https://arxiv.org/abs/2112.15273), which includes a detailed Technical Appendix including information about the designs and models and parameters.

Examples

```r
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)
```

Description

See `pump_power_grid()` for more details.

Usage

```r
pump_mdes_grid(d_m, 
    MTP = NULL, 
    M = 1, 
    target.power, 
    power.definition, 
    tol = 0.01, 
    propZero = NULL, 
    numZero = NULL, 
    nbar, 
    J = 1, 
    K = 1, 
    Tbar, 
    alpha, 
    numCovar.1 = NULL,
```
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.
propZero
scalar; proportion of outcomes assumed to be zero (alternative specification to numZero). length(MDES) should be 1 or equal to (1-propZero)*M.
numZero
scalar; additional number of outcomes assumed to be zero. Please provide NumZero + length(MDES) = M, if length(MDES) is not 1.
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 of 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()
**pump_power**

*Estimate power across definitions (core function)*

**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, 
propZero = NULL, 
M = 1, 
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, 
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.

numZero
scalar; additional number of outcomes assumed to be zero. Please provide NumZero + length(MDES) = M, if length(MDES) is not 1.

propZero
scalar; proportion of outcomes assumed to be zero (alternative specification to numZero). length(MDES) should be 1 or equal to (1-propZero)*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.

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.

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.

drop.zero.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 pumpresult 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,
omega.2 = 0, omega.3 = 0.1,
rho = 0.5)
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 = NULL,
  MDES,
  M = 1,
  nbar,
  J = 1,
  K = 1,
  propZero = NULL,
  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 = NULL,
  long.table = FALSE,
  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.
pump_power_grid

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).

propZero  
Proportion of outcomes that have 0 impact (this will be used to override numZero, only one can be defined)

numZero  
scalar; additional number of outcomes assumed to be zero. Please provide NumZero + length(MDES) = M, if length(MDES) is not 1.

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)
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, if length(MDES) is not 1.
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 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](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)
```

Description

See pump_power_grid() for further details.

Usage

```r
pump_sample_grid(
  d_m, MTP = NULL, M = 1, target.power,
  power.definition, tol = 0.01,
  MDES = NULL, propZero = NULL,
  numZero = NULL, typesample,
  nbar = NULL, J = NULL,
  K = NULL, Tbar,
  alpha,
  numCovar.1 = NULL, numCovar.2 = NULL,
)`
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.

propZero Proportion of outcomes that have 0 impact (this will be used to override numZero, only one can be defined)

numZero scalar; additional number of outcomes assumed to be zero. Please provide NumZero + length(MDES) = M, if length(MDES) is not 1.

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 $nbar \times J \times K$.

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 $J \times K$.

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 = "min", 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.
**update_grid**

**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 = "min1", 
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 ) )
```
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