

Package ‘powergrid’

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Title Power Analysis Across a Grid of Assumptions

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Description Evaluate a function across a grid of parameters. The function may be evaluated once, or many times for simulation. Parallel computing is facilitated. Utilities aim at performing analyses of power and sample size, allowing for easy search of minimum n (or min/max of any other parameter) to achieve a desired minimal level of power (or maximum of any other objective). Plotting functions are included that present the dependency of n and power in relation to further assumptions.

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AddExample	<i>Add an example to an existing PowerPlot or GridPlot</i>
------------	--

Description

Add example arrow(s) to an existing figure created by PowerPlot or GridPlot.

AddExample is a higher level plotting function, so it does not know anything about the figure it draws on top of. Therefore, take care your figure makes sense, by supplying the same arguments `x` and `slicer` that you supplied to the [PowerPlot](#) or [GridPlot](#) you are drawing on top of: With `slicer` you define the plotted plain, with `example` the value on the `x`-axis where the arrow starts. To be sure of a sensible result, use the argument `example` inside `PowerPlot` or `GridPlot`.

Usage

```
AddExample(
  x,
  slicer = NULL,
  example = NULL,
  find_lowest = TRUE,
  target_value = NULL,
  target_at_least = TRUE,
  method = "step",
  summary_function = mean,
  col = grDevices::grey.colors(1, 0.2, 0.2),
  example_text = TRUE,
```

```
    ...
)
```

Arguments

x	Either a power array, or a power_example produced by Example .
slicer	A list, internally passed on to ArraySlicer to cut out a (multidimensional) slice from x. You can achieve the same by appending "slicing" inside argument example. However, to assure that the result of AddExample is consistent with the figure it draws on top of (PowerPlot or GridPlot), copy the arguments x and slicer given to PowerPlot or GridPlot to AddTarget.
example	A list, defining at which value (list element value) of which parameter(s) (list element name(s)) the example is drawn for a power of target_value. You may supply par vector(s) longer than 1 for multiple examples. If example contains multiple parameters to define the example, all must contain a vector of the same length. Be aware that the first element of example defines the parameter x-axis, so this function is not fool proof. See argument slicer above. If x has only one dimension, the example needs not be defined. Ignored if x is a power_example.
target_value, target_at_least, find_lowest, method, example_text, summary_function	See help for PowerPlot. Ignore if x is a power_example.
col	Color of arrow and text drawn.
...	Further arguments to par , as well as length and angle for arrows. These are passed to the points, arrows and text. For the points pch is fixed.

Details

arguments slicer and example:

slicer takes the slice of x that is in the figure, example defines at which value of which parameter, the example is drawn. These arguments' use is the same as in PowerPlot and GridPlot. If you want to make sure that the result of AddExample is consistent with a figure previously created using PowerPlot or GridPlot, copy the argument slicer to such function to AddExample, and define your example in example.

Note however, that:

```
slicer = list(a = c(1, 2)) and example = list(b = c(3, 4))
```

has the same result as:

```
example = list(b = c(3, 4) and a = c(1, 2)) (not defining slicer)
```

Importantly, the the order of example matters here, where the first element defines the x-axis.

multiple examples:

Argument example may contain vectors with length longer than one to draw multiple examples.

Value

invisibly NULL

Author(s)

Gilles Dutilh

See Also[PowerPlot](#), [GridPlot](#)**Examples**

```
## For more examples, see ?PowerPlot

## Set up a grid of n, delta and sd:
sse_pars = list(
  n = seq(from = 10, to = 60, by = 4),
  delta = seq(from = 0.5, to = 1.5, by = 0.1), # effect size
  sd = seq(.1, 1.1, .2)) # Standard deviation
## Define a power function using these parameters:
PowFun = function(n, delta, sd){ # power for a t-test at alpha = .05
  ptt = power.t.test(n = n/2, delta = delta, sd = sd,
    sig.level = 0.05)
  return(ptt$power)
}
## Evaluate PowFun across the grid defined by sse_pars:
power_array = PowerGrid(pars = sse_pars, fun = PowFun, n_iter = NA)

## =====
## PowerPlot
## =====
PowerPlot(power_array,
  slicer = list(sd = .7),
)
AddExample(power_array,
  slicer = list(sd = .7), # be sure to cut out the same plain as above
  example = list(delta = .9),
  target_value = .9,
  col = 'blue')
AddExample(power_array,
  slicer = list(sd = .7),
  example = list(delta = c(.7, 1)), # multiple examples
  target_value = .9,
  col = 'yellow')
## Careful, you can move the slicer argument to example:
AddExample(power_array,
  example = list(delta = 1.2, sd = .7), # delta (x-axis) first
  target_value = .9,
  col = 'green')
## Careful, because you can put the wrong value on x-axis!
AddExample(power_array,
  example = list(sd = .7, delta = 1.2), # sd first?!
  target_value = .9,
  col = 'red')
```

```
## =====
## GridPlot
## =====
GridPlot(power_array, target_value = .9)
AddExample(power_array,
            example = list(delta = 1, sd = .7),
            target_value = .9
          )
## two examples
AddExample(power_array,
            example = list(delta = c(.9, 1.2), sd = c(.5, 1.1)),
            target_value = .9, col = 3
          )
```

ArraySlicer

Cut slice from array (typically of class power_array)

Description

Cut out a slice from an array. The resulting slice may be single- or multidimensional. The function is intended for arrays of class "power_array", and makes sure that the resulting array is of class power_array and keeps and, where needed, updates the object's attributes. These attributes are needed for various functions in the powergrid package to work well.

Usage

```
ArraySlicer(x, slicer = NULL)
```

Arguments

x	An array, in most common use cases an array of class power_array, but may be any array with named dimensions.
slicer	A list whose named elements define at which dimension (the list element names), at which values (the list element values) a slice is taken from power_array. Default NULL returns the unchanged array.

Details

Internally, indexing ([]) is used, but the implementation in ArraySlicer is very flexible allowing for any number of dimensions in any order in the slicer argument. The resulting slice is always an array, also if only one dimension is left. dimnames are kept intact.

Value

An array with reduced dimensions as given by slicer. Note that, relative to a standard array, some additional attributes are passed to be used in the functions in package powergrid

Author(s)

Gilles Dutilh

See Also

[PowerGrid](#), `[.power_array` for reducing the dimensions of an array of class `power_array` using `[]`-indexing.

Examples

```
sse_pars = list(
  n = seq(from = 20, to = 60, by = 5),
  delta = seq(from = 0.5, to = 1.5, by = 0.2),
  sd = seq(.1, .9, .2),
  alpha = c(.05, .025, .1)) # a 4-dimensional grid
PowFun <- function(n, delta, sd, alpha){
  ptt = power.t.test(n = n/2, delta = delta, sd = sd,
                    sig.level = alpha)
  return(ptt$power)
}
power_array = PowerGrid(pars = sse_pars, fun = PowFun, n_iter = NA)
## cut out a 2-dimensional plane:
ArraySlicer(power_array,
             slicer = list(alpha = .1, sd = .9))
## Note that above, the dimension levels are called as numeric values, so the
## following works as well:
ArraySlicer(power_array,
             slicer = list(alpha = 0.1, sd = 0.9))
## They can be called by their actual character values as well:
ArraySlicer(power_array,
             slicer = list(alpha = '0.1', sd = '0.9'))
## (compare with dimnames(power_array))
## the following does not work:
## Not run:
ArraySlicer(power_array,
             slicer = list(alpha = '.1', sd = '.9'))

## End(Not run)
##
## Cut out multiple levels from one dimension
ArraySlicer(power_array,
             slicer = list(alpha = .1, sd = c(.9, .7)))
```

CheckArrayDim

Check the dimensions of a power array

Description

Check the dimensions of a power array

Usage

```
CheckArrayDim(x, required_dim = NULL, condition = "warning", sliced = FALSE)
```

Arguments

x	A power array
required_dim	The number of dimensions required. If NULL just returns the number of dimensions.
condition	If required dimensions are not correct should a warning or error be produced. Ignored if required dimensions is NULL.
sliced	For the condition text should the user be informed the array is sliced. Ignored if required dimensions is NULL.

Value

An integer for the number of dimensions

EnsureSingleFunOut	<i>Ensure a power_array has only a single fun_out value</i>
--------------------	---

Description

If multiple fun_out values are present in the input take the first one.

Usage

```
EnsureSingleFunOut(x, condition = "warning", sliced = FALSE)
```

Arguments

x	A power array
condition	If array is not summarised should a warning or error be produced. Ignored if required dimensions is NULL.
sliced	For the condition text should the user be informed the array is sliced. Ignored if required dimensions is NULL.

Value

A power array with only a single fun_out value

EnsureSummarized	<i>Ensure a power_array is summarized</i>
------------------	---

Description

Ensure a power_array is summarized

Usage

```
EnsureSummarized(x, summary_function = NULL, condition = "warning")
```

Arguments

x	A power array
summary_function	What function should be used to summarize the array, if it is not already summarized.
condition	If array is not summarised should a warning or error be produced. Ignored if required dimensions is NULL.

Value

A summarised power_array

Example	<i>Find combination of parameters required for achieving a desired power (or other objective).</i>
---------	--

Description

Find combination of parameters yielding desired power (or any other target value) in an object of class "power_array".

Usage

```
Example(  
  x,  
  example = NULL,  
  target_value = NULL,  
  target_at_least = TRUE,  
  find_lowest = TRUE,  
  method = "step",  
  summary_function = mean  
)
```

Arguments

x	Object of class <code>power_array</code>
example	List with named elements representing the constellation of parameter values for which the example should be found. The names of this list should match the dimension names of x, their values should be exact values available at these dimensions. See example for an illustration.
target_value	Which value (of typically power) should be achieved at the example.
target_at_least	Logical. Set to TRUE if you aim to achieve a minimum value (e.g., a power must be <i>at least</i> 90%), or FALSE if you want to allow a maximum value (e.g., the width of the expected CI may be <i>at most</i> a certain value).
find_lowest	Logical, indicating whether the example should be found that minimizes a parameter (typically: minimal required n) to achieve the target_value or maximizes this assumption (e.g., maximal allowed SD).
method	Character string, indicating how the location of the example is found, passed on internally to <code>FindTarget</code> . Either "step": walking in steps along the parameter of interest or "lm": Interpolating assuming a linear relation between the parameter of interest and $(qnorm(x) + qnorm(1 - 0.05))^2$. This method "lm" is inspired on the implementation in the <code>sse</code> package by Thomas Fabbro.
summary_function	When x' attribute summarized is FALSE, x is summarized across iterations using this function before searching the example.

Details

In the most typical use case, and this is also the default, `Example` searches the *minimal* n where the power is *at least* equal to the value given by argument `target`. The function is, however, designed much more generically. The explanation below may be less helpful than trying the examples, but for completeness:

Argument `example` slices out a vector from object x, representing the values at the parameter combination given in `example`, thus, along the remaining parameter. Then, `Example` searches along this vector for the *minimal* parameter value where the value of the vector is *at least* equal to `target`. Thus, if the sliced out vector contains values of "power" along the parameter "effect size", it searches the minimal effect size at which the target power is achieved.

Two complications are made to allow for complete flexibility:

1. In the above description, *minimal* can be changed to *maximal* by setting argument `find_lowest` to FALSE. This is useful in the situation where one, e.g., searches for the highest standard deviation at which it is still possible to find a desirable power.
2. In the above description, *at least* can be changed to *at most* by setting `target_at_least` to FALSE. This allows to search, for example, for the minimal sample size where the expected confidence interval is smaller than a certain desired width.

`Example` searches for the minimum or maximum on one parameters (say, the minimum n) given *one single constellation* of further parameters. However, you may want to study how, say, the required n (or any other value) depends on the value of further parameters. The functions `PowerPlot` and

GridPlot offer plotting functionalities to graphically illustrate such dependencies. If you want to find "Examples" as a function of parameter settings and work with these, you can use the workhorse behind 'Example', PowerPlot and Gridplot, [FindTarget](#)

Value

Example returns a list containing:

- "requested_example": the parameter combination at which the power (or whatever the values represent) was searched to achieve level target_value (typically the minimal power, e.g., .9), searching along parameter required_name (typically n).
- "objective": was required_name searched to find the "min" or "max" of x?
- "target_value": which value should the power (or any other value) have?
- "required_name": the parameter searched along to find the minimum (or maximized if slot searched = 'max') to achieve objective. (typically n)
- "required_value": the minimum (or maximum if searched = "max") for parameter required_name (which is typically n)
- "searched": was the "min" or "max" for required_name searched?
- "target_at_least": Is the target_value a minimum (TRUE, as typical for power) or a maximum (FALSE, e.g., an expected uncertainty level)?

Author(s)

Gilles Dutilh

See Also

[PowerGrid](#), [FindTarget](#), [PowerPlot](#), [GridPlot](#)

Examples

```
## =====
## Typical use case: find lowest n for a certain target power
## =====
sse_pars = list(
  n = seq(from = 10, to = 60, by = 2),
  delta = seq(from = 0.5, to = 1.5, by = 0.1), ## effect size
  sd = seq(.1, .9, .2)) ## Standard deviation
PowFun <- function(n, delta, sd){
  ptt = power.t.test(n = n/2, delta = delta, sd = sd,
    sig.level = 0.05)
  return(ptt$power)
}
power_array = PowerGrid(pars = sse_pars, fun = PowFun, n_iter = NA)
##'
ex_out = Example(power_array,
  example = list(delta = .7, sd = .7),
  target_value = .9)
ex_out #
```

```
## =====
## Illustration argument `find_lowest`
## =====
##
## In this example, we search for the *highest sd* for which the power is at
## least .9.
ex_out = Example(power_array,
                  example = list(n = 40, delta = .7),
                  target_value = .9, find_lowest = FALSE)
ex_out # note how the printed result indicates it searched for a maximal
      # permissible sd.

## =====
## Illustration argument `target_at_least`
## =====
##
## In the example below, we search for the lowest n where the expected CI-width
## is not larger than .88.
PowFun <- function(n, delta, sd){
  x1 = rnorm(n = n/2, sd = sd)
  x2 = rnorm(n = n/2, mean = delta, sd = sd)
  CI_width = diff(t.test(x1, x2)$conf.int) # CI95 is saved
}
sse_pars = list(
  n = seq(from = 10, to = 60, by = 5),
  delta = seq(from = 0.5, to = 1.5, by = 0.2),
  sd = seq(.5, 1.5, .2))
## we iterate, and take the average across iterations to get expected CI-width:
n_iter = 20
set.seed(1)
power_array = PowerGrid(pars = sse_pars, fun = PowFun, n_iter = n_iter)
summary(power_array)
## Now, find lowest n for which the average CI width is *smaller than .88*.
ex_out = Example(power_array,
                  example = list(delta = .7, sd = .7),
                  target_value = .88,
                  find_lowest = TRUE, # we search the *lowest* n
                  target_at_least = FALSE # for a *maximal* mean CI width
                  )
ex_out # note how the printed result indicates the target CI is a maximum.

## =====
## When both `find_lowest` and `target_at_least` are FALSE
## =====
##
## In this example, we search for the *highest sd* for which the average CI
## width is still *smaller than or equal to .88*.
ex_out = Example(power_array,
                  example = list(delta = .7, n = 60),
                  target_value = .88,
                  find_lowest = FALSE, # we search the *highest* sd
                  target_at_least = FALSE # for a *maximal* mean CI width
                  )
```

```

    )

ex_out # note how the printed result indicates that the *maximal permissible SD*
      # was found for a CI of *at most .88*.

```

FindTarget

Find requirements for target power (or other objective)

Description

For most use cases of `powergrid`, you will not need this function, but rather use more convenient functions, most notable [Example](#). `Example` shows you the smallest sample size to still find enough power, or the largest standard deviation at which your CI95 does not get too large. More insight about the relation between parameters and the resulting power may be gained with [PowerPlot](#) or [GridPlot](#).

Only if you need to work with, say, the required n for a range of assumptions over and above `PowerPlot` and `GridPlot`, you will need to use `FindTarget`.

`FindTarget` takes as input an array (typically of class `power_array`). `FindTarget` then searches (up or down) along one chosen dimension for a value that meets a set target value (at least or at most). It does so for each combination of the remaining dimensions. Concretely, this may mean: The array contains the calculated power for each combination of dimensions n , effect size, and SD. The function may then find, for each combination of effect size and SD, the lowest n for which power of at least, say, .8 is achieved. The result would be an array of effect size by SD, containing the n 's yielding acceptable power.

Usage

```

FindTarget(
  x,
  par_to_search = "n",
  find_lowest = TRUE,
  target_value = 0.9,
  target_at_least = TRUE,
  method = "step"
)

```

Arguments

<code>x</code>	An array, most commonly of class <code>power_array</code> , possibly the result of taking a slice of an object of class <code>power_array</code> using ArraySlicer or the <code>power_array</code> <code>[]</code> -indexing method.
<code>par_to_search</code>	Which parameter should be searched to achieve the required target value. In the typical power analysis case, this is n .

find_lowest	If TRUE, the lowest value of par_to_search is found that yields a value that meets the target. This is typical for n in a sample size estimation, where one searches the lowest n to achieve a certain power. For, e.g. the variance, one would however search for the maximum where the target power can still be achieved.
target_value	The required value in x (e.g., .9, if the values represent power)
target_at_least	Is the target_value a minimum (e.g., the power) or a maximum (e.g., the size of a confidence interval)
method	How is the required par_to_search to achieve target_value found. Either 'step': walking in steps along par_to_search or 'lm': Interpolating assuming a linear relation between par_to_search and $(\text{qnorm}(x) + \text{qnorm}(1 - 0.05))^2$. Setting 'lm' is inspired on the implementation in the sse package by Thomas Fabbro.

Details

By default FindTarget searches along the dimension called n (par_to_search), searching for the lowest value (find_lowest = TRUE) where the array contains a value of at least (target_at_least = TRUE) .9 (the target_value), thus finding the minimal sample size required to achieve a power of 90%. These arguments may seem a bit confusing at first, but they allow for three additional purposes:

First, the implementation also allows to search for a value that is *at most* the target_value, by setting target_at_least to FALSE. This may be used, for example, when the aim is to find a sample size yielding a confidence interval that is not bigger than some maximum width.

Second, the implementation allows to search along another *named* dimension of x than n.

Third, the implementation allows to search for a certain target value to be achieved by maximizing (find_lowest = FALSE) the parameter on the searched dimension. This may be used, for example, when the aim is to find the maximum standard deviation at which a study's power is still acceptable.

FindTarget is most often called as the workhorse of [Example](#), [PowerPlot](#) or [GridPlot](#).

Value

Returns an array or vector: containing the value that is found for the par_to_search (say, n) meeting the target following above criteria (say, the lowest n for which the power is larger than .9), for each crossing of the levels of the other dimensions (say, delta, SD).

Author(s)

Gilles Dutilh

See Also

[PowerGrid](#), [Example](#), [PowerPlot](#)

Examples

```
## =====
## A basic power analysis example:
## =====
sse_pars = list(
  n = seq(from = 10, to = 60, by = 2),
  sig_level = seq(.01, .1, .01),
  delta = seq(from = 0.5, to = 1.5, by = 0.2), ## effect size
  sd = seq(.1, .9, .2)) ## Standard deviation
PowFun <- function(n, sig_level, delta, sd){
  ptt = power.t.test(n = n/2, delta = delta, sd = sd,
                    sig.level = sig_level)
  return(ptt$power)
}
power_array = PowerGrid(pars = sse_pars, fun = PowFun, n_iter = NA)
summary(power_array) # four dimensions

## We can use Example so find the required sample size, but only for one example:
Example(power_array,
        example = list(delta = .7, sd = .7, sig_level = .05),
        target_value = .9)

## If we want to see the required sample size for all delta's, we can use
## FindTarget. Get the minimal n needed for achieving a value of 0.9, at sd =
## .3:
n_by_delta_sd_03 = FindTarget(power_array[, , sig_level = '0.05', , sd = '0.3'],
                              par_to_search = 'n',
                              target_value = .9)

n_by_delta_sd_03
## just as an illustration, a figure (that can be much more aesthetically made
## using PowerPlot)
plot(as.numeric(names(n_by_delta_sd_03)),
     n_by_delta_sd_03, type = 'l')

## =====
## Higher dimensionality
## =====

## The function works also for higher dimensionality:
n_by_delta_sd = FindTarget(power_array,
                           par_to_search = 'n',
                           target_value = .85)

## what is the minimum n to achieve .85 for different values of delta, sd,
## when sig_level = 0.05:
n_by_delta_sd[5, , ] # note that for some combinations of delta and sd, there is
# no n yielding the required power at this significance
# level (NAs).
```

GridPlot

Plot requirements for achieving a target power as a function of assumptions about two parameters

Description

Plots how the required sample size (or any other parameter) to achieve a certain power (or other objective) depends on two further parameters.

Usage

```
GridPlot(
  x,
  slicer = NULL,
  y_par = NULL,
  x_par = NULL,
  l_par = NULL,
  example = NULL,
  find_lowest = TRUE,
  target_value = 0.9,
  target_at_least = TRUE,
  method = "step",
  summary_function = mean,
  col = NULL,
  example_text = TRUE,
  title = NULL,
  axes = TRUE,
  par_labels = NULL,
  add_legend = TRUE,
  xlim = NULL,
  ylim = NULL,
  smooth = FALSE,
  ...
)
```

Arguments

<code>x</code>	An object of class "power_array" (from powergrid).
<code>slicer</code>	If the parameter grid of <code>x</code> has more than 3 dimensions, a 3-dimensional slice must be cut out using <code>slicer</code> , a list whose elements define at which values (the list element value) of which parameter (the list element name) the slice should be cut.
<code>y_par</code>	Which parameter is searched for the minimum (or maximum if <code>find_lowest == FALSE</code>) yielding the target value; and shown on the y-axis. If <code>NULL</code> , <code>y_par</code> is set to the first, <code>x_par</code> to the second, and <code>l_par</code> to the third dimension name of 3-dimensional array <code>x</code> . If you want another than the first dimension as <code>y_par</code> , you need to see <code>y_par</code> , <code>x_par</code> , and <code>l_par</code> explicitly.

<code>x_par, l_par</code>	Which parameter is varied on the x-axis, and between lines, respectively. If none of <code>y_par</code> , <code>x_par</code> and <code>l_par</code> are given, the first, second, and third dimension of <code>x</code> are mapped to <code>y_par</code> , <code>x_par</code> , and <code>l_par</code> , respectively.
<code>example</code>	A list defining for which combination of levels of <code>l_par</code> and <code>x_par</code> an example arrow should be drawn. List element names indicate the parameter, element value indicate the values at which the example is drawn.
<code>find_lowest</code>	Logical, indicating whether the example should be found that minimizes an assumption (e.g., minimal required <code>n</code>) to achieve the <code>target_value</code> or an example that maximizes this assumption (e.g., maximally allowed SD).
<code>target_value</code>	The target power (or any other value stored in <code>x</code>) that should be matched.
<code>target_at_least</code>	Logical. Should <code>target_value</code> be minimally achieved (e.g., power), or maximally allowed (e.g., estimation uncertainty).
<code>method</code>	The method to find the required parameter values, see <code>Example</code> and <code>FindTarget</code> .
<code>summary_function</code>	If <code>x</code> is an object of class <code>power_array</code> where attribute <code>summarized</code> is <code>FALSE</code> (indicating individual iterations are stored in dimension <code>iter</code> , the iterations dimension is aggregated by <code>summary_fun</code> . Otherwise ignored.
<code>col</code>	A vector with the length of <code>l_par</code> defining the color(s) of the lines.
<code>example_text</code>	When an example is drawn, should the the required par value, and the line parameter value be printed alongside the arrow(s).
<code>title</code>	Character string, if not <code>NULL</code> , replaces default figure title. Replaces <code>main</code> if specified by <code>...</code> .
<code>axes</code>	Logical defining whether or not axes are drawn.
<code>par_labels</code>	Named vector where elements names represent the parameters that are plotted, and the values set the desired labels.
<code>add_legend</code>	Should the legend be automatically generated (<code>default = TRUE</code>), set to <code>FALSE</code> and add afterwards for more flexibility.
<code>xlim, ylim</code>	See <code>?graphics::plot</code> .
<code>smooth</code>	Logical. If <code>TRUE</code> , a 5th order polynomial is fitted though the points constituting each line for smoothing.
<code>...</code>	Further arguments to <code>par</code> , <code>plot</code> , <code>axis</code> and <code>lines</code> . A few exceptions (e.g. <code>y</code>) are ignored with a warning.

Details

In the most typical use case, the y-axis shows the *minimal* sample size required to achieve a power of *at least* `target_value`, assuming the value of a parameter on the x-axis, and the value of another parameter represented by each line.

The use of this function is, however, not limited to finding a minimum `n` to achieve at least a certain power. See help of `Example` to understand the use of `target_at_least` and `fin_min`.

If the input to argument `x` (class `power_array`) contains iterations that are not summarized, it will be summarized by `summary_function` with default mean.

Note that a line may stop in a corner of the plotting region, not reaching the margin. This is often correct behavior, when the `target_value` level is not reached anywhere in that corner of the parameter range. In case `n` is on the y-axis, this may easily be solved by adding larger sample sizes to the grid (consider `Update`), and then adjusting the y-limit to only include the values of interest.

Graphical parameters:

Graphical parameters that are allowed as input to the functions `graphics::plot`, `graphics::lines`, `graphics::image` and `graphics::axis`, including all parameters available in `par()` are passed on to these functions internally. Not passed through are "x", "y", "z", "type", "at", and parameters that are explicit arguments to `GridPlot`.

Value

A list with graphical information to use in further plotting.

Author(s)

Gilles Dutilh

See Also

[PowerGrid](#), [AddExample](#), [Example](#), [PowerPlot](#) for similar plotting of just 2 parameters, at multiple power (target value) levels.

Examples

```
sse_pars = list(
  n = seq(from = 2, to = 100, by = 2),
  delta = seq(from = 0.1, to = 1.5, by = 0.05), ## effect size
  sd = seq(.1, .9, .1)) ## Standard deviation
PowFun = function(n, delta, sd){
  ptt = power.t.test(n = n/2, delta = delta, sd = sd,
    sig.level = 0.05)
  return(ptt$power)
}
power_array = PowerGrid(pars = sse_pars, fun = PowFun, n_iter = NA)
GridPlot(power_array, target_value = .8)
## If that's too many lines, cut out a desired number of slices
GridPlot(power_array,
  slicer = list(sd = seq(.1, .9, .2)),
  target_value = .8)

## adjust labels, add example
GridPlot(power_array, target_value = .9,
  slicer = list(sd = seq(.1, .9, .2)),
  y_par = 'n',
  x_par = 'delta',
  l_par = 'sd',
  par_labels = c('n' = 'Sample Size',
    'delta' = 'Arm Difference',
    'sd' = 'Standard Deviation'),
  example = list(sd = .7, delta = .6))
```

```
## add additional examples using AddExample. Note that these do not contain
## info about the line they refer to.
AddExample(power_array,
            target_value = .9,
            example = list(delta = c(.5, .8), sd = c(.3, .7)),
            col = 3
            )

## Above, GridPlot used the default: The first dimension is what you search
## (often n), the 2nd and 3rd define the grid of parameters at which the
## search # is done. Setting this explicitly, with x, y, and l-par, it looks
## like:
GridPlot(power_array, target_value = .8,
          slicer = list(sd = seq(.1, .9, .2)),
          y_par = 'n', # search the smallest n where target value is achieved
          x_par = 'delta',
          l_par = 'sd')

## You may also want to have different parameters on lines and axes:
GridPlot(power_array, target_value = .8,
          y_par = 'delta', # search the smallest delta where target value is achieved
          x_par = 'sd',
          l_par = 'n')
## Too many lines! Take some slices again:
GridPlot(power_array, target_value = .9,
          slicer = list(n = c(seq(10, 70, 10))),
          y_par = 'delta',
          x_par = 'sd',
          l_par = 'n', method = 'step')
```

PowerDF

Transform power_array into power_df

Description

Transforms an object of class `power_array` to a `data.frame`, where values are stored in column `x`, and all other dimensions are columns. Some may find this "more tidy" to work with.

The class of the `data.frame` becomes `'c("power_df", "data.frame")`, enabling generics for `data.frame`. Note that the class `"power_df"` has currently no use but is included for future compatibility.

Usage

```
PowerDF(x)
```

Arguments

`x` Object of class `power_array`

Value

An object of with classes `c("power_df", "data.frame")`, with the same attributes as `x`, aside from array-native attributes (`dimnames`, `dim`), plus the `data.frame` attributes `names` and `row_names`.

Author(s)

Gilles Dutilh

See Also

[PowerGrid](#)

Examples

```
## Define grid of assumptions to study:
sse_pars = list(
  n = seq(from = 10, to = 50, by = 20),      # sample size
  delta = seq(from = 0.5, to = 1.5, by = 0.5), # effect size
  sd = seq(.1, 1, .3))                      # standard deviation

## Define function that calculates power based on these assumptions:
PowFun <- function(n, delta, sd){
  ptt = power.t.test(n = n/2, delta = delta, sd = sd,
                    sig.level = 0.05)
  return(ptt$power)
}

## Evaluate at each combination of assumptions:
powarr = PowerGrid(pars = sse_pars, fun = PowFun, n_iter = NA)
print(PowerDF(powarr))
```

PowerGrid

Evaluate function (iteratively) at a grid of input arguments

Description

PowerGrid is an `apply`-like function, allowing to evaluate a function at the crossings of a set of parameters. The result is saved in an array with attributes that optimize further usage by functions in package `powergrid`. In particular, performing a function iteratively (using parallel computing if required) is implemented conveniently. The typical use is for evaluating statistical power at a grid of assumed parameters.

Usage

```
PowerGrid(
  pars,
  fun,
  more_args = NULL,
```

```

    n_iter = NA,
    summarize = TRUE,
    summary_function = mean,
    parallel = FALSE,
    n_cores = future::availableCores() - 1,
    progress_bar = FALSE
  )

```

Arguments

<code>pars</code>	A list where each element is a numeric vector of values named as one of the arguments of <code>fun</code> . <code>fun</code> is applied to the full grid crossing the values of each of these parameters. If you aim to study other than numeric parameters, see details.
<code>fun</code>	A function to be applied at each combination of <code>pars</code> . Arguments may contain all element names of <code>pars</code> and <code>more_args</code> . Output should always be a numeric vector, typically of length one. However, if you want to work with multiple outputs, each can be an element of the returned numeric vector.
<code>more_args</code>	Fixed arguments to <code>fun</code> that are not in <code>pars</code> . (internally used in <code>.mapply</code> for supplying argument <code>MoreArgs</code>)
<code>n_iter</code>	If not <code>NA</code> , function <code>fun</code> is applied <code>n_iter</code> times at each point in the grid defined by <code>pars</code> .
<code>summarize</code>	Logical indicating whether iterations (if <code>n_iter</code> is given) are to be summarized by <code>summary_function</code> .
<code>summary_function</code>	A function to be applied to aggregate across iterations. Defaults to <code>mean</code> , ignored when <code>keep_iters == TRUE</code> or when <code>is.na(n_iter)</code> .
<code>parallel</code>	Logical indicating whether parallel computing should be applied. If <code>TRUE</code> , <code>future::future_replicate</code> is used internally.
<code>n_cores</code>	Passed on to <code>future_replicate</code>
<code>progress_bar</code>	Logical argument to request output of iterations using a progress bar. See details section.

Details

Function `fun` is evaluated at each combination of the argument values listed in `pars` and its results are stored in an array of class `power_array`, whose dimensions (and `dimnames()`) are defined by `pars`. For this to work, the element names of `pars` must match the argument names of `fun`.

Further arguments to `fun`:

If input parameters to `fun` are not to be part of the grid, but rather further settings, these can be passed on to `fun` through the argument `more_args` as a list with names reflecting the arguments of `fun` to be set.

Storing multiple outputs from `fun`:

You may have a function `fun` that returns a vector with length larger than one, as long as it is a single vector. When `fun` returns a vector with length larger than one, the `power_array` will have an additional dimension `fun_out`, with levels named after the names of `fun`'s return vector (if given).

Non-numeric parameters:

You may want to study the effect of non-numeric parameters. This option is not supported for the argument pars, since the essential powergrid functions [Example](#), [PowerPlot](#), and [GridPlot](#) need a direction to search. Nonetheless, you can study non-numeric parameters by having function fun returning multiple values, as described above.

Evaluating a function over iterations:

If n_iter is not NA (the default) but an integer, function fun is evaluated n_iter times. This will add an additional dimension 'iter' to the resulting array of class power_array. If your simulation is heavy, you may wanna set parallel = TRUE and choose the n_cores, invoking parallel computing using `tfuture::future_replicate`.

You may summarize the object with individual iterations across these iterations using function [SummarizeIterations](#). Note that both summarized and non-summarized output of PowerGrid have class power_array. The summary status is saved in the attributes. This allows the powergrid utilities [Example](#), [PowerPlot](#), and [GridPlot](#) to do something sensible also with non-summarized objects.

Reproducibility:

The current status of .Random.seed is stored in the attribute random_seed (which is a list). To reproduce a call of PowerGrid involving randomness, precede new call to PowerGrid by `.Random.seed = attr(<your_power_array>, which = 'random.seed')[[1]]`. Note that if you `Refine()` your power_array, the .Random.seed at the moment of updating is appended to the random.seed attribute. So, to reconstruct a refined power_array, run the original call to PowerGrid after `.Random.seed = attr(<your_power_array>, which = 'random.seed')[[1]]`, and the the call to `Refine` after `.Random_seed = attr(<your_power_array>, which = 'random.seed')[[2]]`, etc.

Progress bar:

By default PowerGrid does not report progress. To return the optional progress bar (`progress_bar = TRUE`), the `progressr` package must be installed. As required by the design of that package, the progress handler must be explicitly activated before running your simulation. For that, run `progressr::handlers(global = TRUE)` in the current R console (not sent to the console from `quarto` for example).

Value

An array of class "power_array", with attributes containing informations about input arguments, summary status, the presence of multiple function outputs and more. This object class is handled sensibly by functions in package powergrid, including [Example](#), [PowerPlot](#), and [GridPlot](#).

Author(s)

Gilles Dutilh

See Also

[Refine\(\)](#) for adding iterations or parameter combinations to existing power_array object, [SummarizeIterations\(\)](#) for summarizing a power_array object containing individual iterations, [ArraySlicer\(\)](#) and `[.power_array]` for reducing the dimensiona of a power_array object, correctly updating its attributes.

Examples

```
## =====
## most basic use case, calculating power when
## power function is available:
## =====

## Define grid of assumptions to study:
sse_pars = list(
  n = seq(from = 10, to = 60, by = 2),      # sample size
  delta = seq(from = 0.5, to = 1.5, by = 0.2), # effect size
  sd = seq(.1, .9, .2))                     # standard deviation

## Define function that calculates power based on these assumptions:
PowFun <- function(n, delta, sd){
  ptt = power.t.test(n = n/2, delta = delta, sd = sd,
    sig.level = 0.05)
  return(ptt$power)
}

## Evaluate at each combination of assumptions:
powarr = PowerGrid(pars = sse_pars, fun = PowFun, n_iter = NA)
summary(powarr)

## =====
## Use powergrid utilities on result
## =====

## get required sample size n, when delta is .7, sd = .5, for achieving a
## power of 90%:
Example(powarr, example = list(delta = .7, sd = .5), target_value = .9)

## Draw a figure illustrating how the required n depends on delta (given an
## sd of .7):
PowerPlot(powarr,
  slicer = list(sd = .7), # slice out the plane with sd = .7
  target_value = .9, # set target power to 90%, defining the thick line
  example = list(delta = .7) # Highlight the example with arrow
)

## Slice out a sub-array (making sure attributes stay intact for further use in
## powergrid):

only_n20_delta1.1 =
  ArraySlicer(powarr, slicer = list(
    n = 20,
    delta = 1.1))
summary(only_n20_delta1.1)

## Indexing may also be used, but note that the name of the remaining dimension
## is lost. Therefore, use ArraySlicer when you want to keep working with the
## object in powergrid.
only_n20_delta1.1 = powarr[n = 20, delta = 1.1, ]
summary(only_n20_delta1.1)
```

```

## =====
## Simulation over iterations when no power
## function is available
## =====

## Using the same assumptions as above
sse_pars = list(
  n = seq(from = 10, to = 60, by = 5),
  delta = seq(from = 0.5, to = 1.5, by = 0.2),
  sd = seq(.5, 1.5, .2))

## Define a function that results in TRUE or FALSE for a successful or
## non-successful (5% significant) simulated trial:
PowFun <- function(n, delta, sd){
  x1 = rnorm(n = n/2, sd = sd)
  x2 = rnorm(n = n/2, mean = delta, sd = sd)
  t.test(x1, x2)$p.value < .05
}

## In call to PowerGrid, setting n_iter prompts PowerGrid to evaluate
## the function iteratively at each combination of assumptions:
n_iter = 20
powarr = PowerGrid(pars = sse_pars, fun = PowFun,
                   n_iter = n_iter)

## By default, the iterations are summarized (by their mean), so:
dimnames(powarr)
summary(powarr) # indicates that iterations were summarized (not stored)

## =====
## keeping individual iterations
## =====

## To keep individual iterations, set summarize to FALSE:

powarr_no_summary = PowerGrid(pars = sse_pars, fun = PowFun,
                              n_iter = n_iter, summarize = FALSE)
dimnames(powarr_no_summary) # additional dimension "iter"
summary(powarr_no_summary)

## To summarize this object containing iterations, use the SummarizeIterations
## function. Among other things, this assures that attributes relevant for
## further use in powergrid's functionality are kept intact.

powarr_summarized =
  SummarizeIterations(powarr_no_summary, summary_function = mean)
dimnames(powarr_summarized)
summary(powarr_summarized)

## This summarized `power_array` is no different from a version that was
## directly summarized.

```

```
## Note that Example and Powerplot detect when a `power_array` object is not
#summarized, and behave sensibly with a warning:
Example(powarr_no_summary, example = list(delta = .7, sd = .5), target_value = .9)

PowerPlot(powarr_no_summary,
  slicer = list(sd = .7), # slice out the plane with sd = .7
  target_value = .9, # set target power to 90%, defining the thick line
  example = list(delta = .7) # Highlight the example with arrow
)

#=====
# Multiple outputs are automatically handled #
#=====

## Parameter assumptions
sse_pars = list(
  n = seq(from = 10, to = 60, by = 2),
  delta = seq(from = 0.5, to = 1.5, by = 0.2),
  sd = seq(.5, 1.5, .2))

## A function with two outputs (the power at two significance levels)
TwoValuesFun <- function(n, delta, sd){
  p5 = power.t.test(n = n, delta = delta, sd = sd, sig.level = .05)$power
  p1 = power.t.test(n = n, delta = delta, sd = sd, sig.level = .01)$power
  return(c('p5' = p5, 'p1' = p1))
}

powarr_two_returns = PowerGrid(sse_pars, TwoValuesFun)

## multiple outputs result in an additional dimension:
dimnames(powarr_two_returns)
summary(powarr_two_returns)

## note that you need to tell Example and other powergrid functions, which
## of the outputs you are interested in:
Example(powarr_two_returns, example = list(delta = .7, sd = .5, fun_out = 'p1'),
  target_value = .9)

PowerPlot(powarr_two_returns,
  slicer = list(sd = .7, fun_out = 'p1'), # slice out the plane with the
                                          # output of interest
  target_value = .9, # set target power to 90%, defining the thick line
  example = list(delta = .7) # Highlight the example with arrow
)
```

Description

Plot (a slice of) an object of class `power_array`. Main purpose is to illustrate the relation between two parameters (e.g., effect size on the x-axis and n on the y-axis) for a given target power. An example may be highlighted by drawing an arrow at the combination of parameters deemed most likely.

Usage

```
PowerPlot(
  x,
  slicer = NULL,
  par_to_search = "n",
  example = NULL,
  find_lowest = TRUE,
  target_value = 0.9,
  target_at_least = TRUE,
  method = "step",
  summary_function = mean,
  target_levels = c(0.8, 0.9, 0.95),
  col = grDevices::grey.colors(1, 0.2, 0.2),
  shades_of_grey = TRUE,
  example_text = TRUE,
  title = NULL,
  axes = TRUE,
  labcex = 1.2,
  par_labels = NULL,
  smooth = NA,
  ...
)
```

Arguments

<code>x</code>	An object of class <code>power_array</code> (from <code>powergrid</code>).
<code>slicer</code>	If the parameter grid for which ‘x’ was constructed has more than 2 dimensions, a 2-dimensional slice may be cut out using <code>slicer</code> , which is a list whose elements define at which values (the list element value) of which parameter (the list element name) the slice should be cut out.
<code>par_to_search</code>	The variable whose minimum (or maximum, when <code>find_lowest == FALSE</code>) is searched for achieving the <code>target_levels</code> .
<code>example</code>	If not <code>NULL</code> , a list of length one, defining at which value (list element value) of which parameter (list element name) the example is drawn for a power of <code>target_value</code> . You may supply a vector longer than 1 for multiple examples.
<code>find_lowest</code>	Logical, indicating whether the example should be found that minimizes an assumption (e.g., minimal required n) to achieve the <code>target_value</code> or an example that maximizes this assumption (e.g., maximally allowed SD).
<code>target_value</code>	The power (or whatever the target is) for which the example, if requested, is drawn. Also defines which of the power lines is drawn with a thicker line width, among or in addition to the power lines defined by <code>target_levels</code> .

target_at_least	Logical. Should the target value be minimally achieved (e.g., power), or maximally allowed (e.g., estimation uncertainty).
method	Method used for finding the required par_to_search needed to achieve target_value. Either step: walking in steps along par_to_search or lm: Interpolating assuming a linear relation between par_to_search and $(qnorm(x) + qnorm(1 - 0.05))^2$. The setting lm is inspired on the implementation in the sse package by Thomas Fabbro.
summary_function	If x is an object of class power_array where attribute summarized is FALSE (and individual iterations are stored in dimension iter, the iterations dimension is aggregated by summary_fun. Otherwise ignored.
target_levels	For which levels of power (or whichever variable is contained in x) lines are drawn.
col	Color for the contour lines. Does not effect eventual example arrows. Therefore, use AddExample.
shades_of_grey	Logical indicating whether greylevels are painted in addition to isolines to show power levels.
example_text	When an example is drawn, should the the required par value be printed alongside the arrow(s)
title	Character string, if not NULL, replaces default figure title.
axes	Logical defining whether or not axes are drawn.
labcx	Numeric value passed to 'contour, specifying the size of the contour labels.
par_labels	Named vector with elements named as the parameters plotted, with as values the desired labels.
smooth	Numeric, defaults to NA, meaning no smoothing. Non NA value is used as argument span for smoothing with stats::loess, regressing the contour values on the x and y-axis. Suggested value is .35. Functionality implemented for consistency with sse package, but use is discouraged, since regressing the contour values flattens the contour plot, thereby <i>biasing</i> the contour lines.
...	Further arguments to par, axis and image. A few exceptions (e.g. y) are ignored with a warning. ... is also passed directly to AddExample

Details

The most common use case may be plotting the required n (on the y-axis) as a function of some other parameter (e.g., effect size, on the x-axis) for achieving a certain level of statistical power. The default argument settings reflect this use case.

Flexible plotting:

The plotting is, however, more flexible.

Any variable on the axes:

You can flip the axes by setting a different par_to_search (which defines the y-axis). The other parameter is automatically chosen to be drawn on the x-axis.

Maximizing a parameter:

One may also search not the minimum, as in the case of sample size, but the maximum, e.g., the highest sd at which a certain power may still be achieved. In this case, the `par_to_search` is `sd`, and `find_lowest = FALSE`.

When smaller is better:

In the standard case of power, higher is better, so you search for a *minimal* level of power. One may however also aim at, e.g., a *maximal* width of a confidence interval. For this purpose, set `target_at_least` to `FALSE`. See Example for more details about `find_lowest` and `target_at_least`.

Graphical parameters:

Graphical parameters that are allowed as input to the functions `graphics::plot`, `graphics::lines`, `graphics::image` and `graphics::axis`, including all parameters available in `par()` are passed on to these functions internally. Not passed through are "x", "y", "z", "type", "at", and parameters that are explicit arguments to `PowerPlot`.

Value

A list containing the coordinate arguments `x`, `y`, and `z`, as passed to `image()` internally.

Author(s)

Gilles Dutilh

See Also

[PowerGrid](#), [AddExample](#), [Example](#), [GridPlot](#) for plotting interdependencies of 3 parameters.

Examples

```
## =====
## Typical use case: minimal n for power
## =====
## What's the minimal sample size n, given the combination of sd and delta.

## Set up a grid of n, delta and sd:
sse_pars = list(
  n = seq(from = 10, to = 60, by = 4),
  delta = seq(from = 0.5, to = 1.5, by = 0.1), # effect size
  sd = seq(.1, 1.1, .2)) # Standard deviation

## Define a power function using these parameters:
PowFun = function(n, delta, sd){ # power for a t-test at alpha = .05
  ptt = power.t.test(n = n/2, delta = delta, sd = sd,
                    sig.level = 0.05)
  return(ptt$power)
}

## Evaluate PowFun across the grid defined by sse_pars:
power_array = PowerGrid(pars = sse_pars, fun = PowFun, n_iter = NA)
```

```

## explore power graphically in the situation where sd = .7, including an
## example situation where delta is .9:
PowerPlot(power_array,
          slicer = list(sd = .7),
          example = list(delta = c(.7, .9)), # two examples
          target_value = .9 # 90% power
        )

## Some graphical adjustments. Note that example is drawn on top of
## PowerPlot now.
PowerPlot(power_array,
          slicer = list(sd = .7),
          par_labels = c(n = 'Total Sample Size',
                        delta = 'Effect Size',
                        sd = 'Standard Deviation'),
          target_levels = c(.8, .9), # draw fewer power isolines
          target_value = NA # no specific power target (no line thicker)
        )
AddExample(power_array,
          slicer = list(sd = .7),
          example = list(delta = .9),
          target_value = .9,
          col = 'Orange', lwd = 3)

## =====
## Less typical use case:
## minimal delta for power, given sd, as a function of n
## =====
## You can easily change what you search for. For example: At each sample size n,
## what would be the minimal effect size delta there must be for the target
## power to be achieved?

PowerPlot(power_array,
          par_to_search = 'delta',
          slicer = list(sd = .7))

## =====
## Less typical use case:
## *maximum sd* for power, given n, as a function of delta
## =====
## You're not limited to study n at all, nor to searching a minimum: When
## your n is given to be 30, what is the largest sd at which we still find
## enough power? (as a function of delta on the x-axis)

PowerPlot(power_array,
          par_to_search = 'sd',
          find_lowest = FALSE,
          slicer = list(n = 30))

## Adding an example works the same: If we expect a delta of 1, and the n =
## 30, what is the maximal SD we can have still yielding 90% power?

AddExample(power_array,

```

```

find_lowest = FALSE,
slicer = list(n = 30),
example = list(delta = 1),
target_value = .9)

```

print.power_array *print*

Description

Method for printing objects of class power_array. `##'` Prints a power_array as a default array with a short summary about its contents.

Usage

```

## S3 method for class 'power_array'
print(x, ...)

```

Arguments

<code>x</code>	object of class power_array
<code>...</code>	passed on to cat

Value

Nothing

Author(s)

Gilles Dutilh

See Also

[PowerGrid](#)

Examples

```

## Define grid of assumptions to study:
sse_pars = list(
  n = seq(from = 10, to = 50, by = 20),      # sample size
  delta = seq(from = 0.5, to = 1.5, by = 0.5), # effect size
  sd = seq(.1, 1, .3))                      # standard deviation

## Define function that calculates power based on these assumptions:
PowFun <- function(n, delta, sd){
  ptt = power.t.test(n = n/2, delta = delta, sd = sd,
    sig.level = 0.05)
  return(ptt$power)
}

```

```
## Evaluate at each combination of assumptions:
powarr = PowerGrid(pars = sse_pars, fun = PowFun, n_iter = NA)
print(powarr)
```

print.power_example	<i>Print example</i>
---------------------	----------------------

Description

Print method for class power_example.

Usage

```
## S3 method for class 'power_example'
print(x, ...)
```

Arguments

- x object of class power_example
- ... passed on to cat

Details

Print short informative output for object of class power_example.

Value

nothing

Author(s)

Gilles Dutilh

Refine	<i>Refine or extend the result of PowerGrid</i>
--------	---

Description

Add further results to an existing power_array (created by PowerGrid or by another call of Refine), adding further values in pars and/or larger n_iter.

Usage

```
Refine(old, n_iter_add = 1, pars = NULL, ...)
```

Arguments

<code>old</code>	the object of class <code>power_array</code> to extend
<code>n_iter_add</code>	the number of iterations to <i>add</i> to <code>old</code>
<code>pars</code>	the new parameter grid to evaluate across
<code>...</code>	further arguments passed on to <code>PowerGrid</code> internally.

Details

This function allows extending the number of iterations, as well as changing the parameter grid across which the function of interest is evaluated. Being able to do both at the same time is handy in cases where calculation takes significant time: You may first only evaluate a broad grid of parameters with a low number of iterations using `PowerGrid`. Then, using `Refine`, you can zoom in on a certain section of the parameter grid (and increase resolution in the focal range), and evaluate with a higher number of iterations.

If `pars == NULL`, `Refine` extends `old` by adding iterations `n_iter_add` to the existing `power_array` (applying the original function `attr(old, which = 'sim_function')`).

If `pars` is given and different from the original `pars` (`attr(old, which = 'pars')`), the function is evaluated at additional crossings of parameters. This means that the resulting array may have empty cells, or cells with different numbers of iterations. This is a feature, not a bug. It may result in less aesthetic plotting, however.

For details about handling the random seed, see [PowerGrid](#).

Value

object of class `power_array`, containing `old`, extended by `pars` and/or `n_iter_add`.

Author(s)

Gilles Dutilh

See Also

[PowerGrid](#)

Examples

```
## =====
## very simple example with one parameter
## =====
pars = list(x = 1:2)
fun = function(x){round(x+runif(1, 0, .2), 3)} # nonsense function
set.seed(1)
original = PowerGrid(pars = pars,
                    fun = fun,
                    n_iter = 3,
                    summarize = FALSE)
refined = Refine(original, n_iter_add = 2, pars = list(x = 2:3))
## note that refined does not have each parameter sampled in each iteration
```

```

## =====
## a realistic example, simply increasing n_iter
## =====
PowFun <- function(n, delta){
  x1 = rnorm(n = n/2, sd = 1)
  x2 = rnorm(n = n/2, mean = delta, sd = 1)
  t.test(x1, x2)$p.value < .05
}
sse_pars = list(
  n = seq(10, 100, 5),
  delta = seq(.5, 1.5, .1))
##
n_iter = 20
set.seed(1)
power_array = PowerGrid(pars = sse_pars,
                        fun = PowFun,
                        n_iter = n_iter,
                        summarize = FALSE)

summary(power_array)
## add iterations
power_array_up = Refine(power_array, n_iter_add = 30)
summary(power_array_up)

## =====
## Starting coarsely, then zooming in
## =====
sse_pars = list(
  n = c(10, 50, 100, 200), # finding n "ballpark"
  delta = c(.5, 1, 1.5)) # finding delta "ballpark"
n_iter = 60
power_array = PowerGrid(pars = sse_pars,
                        fun = PowFun,
                        n_iter = n_iter,
                        summarize = FALSE)

summary(power_array)
PowerPlot(power_array)
## Based on figure above, let's look at n between 50 and 100, delta around .9

sse_pars = list(
  n = seq(50, 100, 5),
  delta = seq(.7, 1.1, .05))
set.seed(1)
power_array_up = Refine(power_array, n_iter_add = 555, pars = sse_pars)
summary(power_array_up)
PowerPlot(power_array_up)

## That looks funny! It's because the default summary mean does not deal
## with the empty value in the grid. Solution is in illustration below.

## A visual illustration of this zooming in, in three figures
layout(t(1:3))
PowerPlot(power_array, title = 'Course grid to start with')

```

```

PowerPlot(power_array_up, summary_function = function(x)mean(x, na.rm = TRUE),
          title = 'Extra samples at finer grid\n(looks funny with large empty cells)')
PowerPlot(power_array_up,
          slicer = list(n = seq(50, 100, 5),
                        delta = seq(.7, 1.1, .05)),
          summary_function = function(x)mean(x, na.rm = TRUE),
          title = 'Zoomed in')
layout(1)

```

SummarizeIterations *Summary of object that has individual iterations saved.*

Description

Summarizes objects of class `power_array` that have individual iterations saved.

Usage

```
SummarizeIterations(x, summary_function, ...)
```

Arguments

<code>x</code>	Object of class <code>power_array</code>
<code>summary_function</code>	function to apply across iterations
<code>...</code>	Further arguments passed to 'summary_function'

Value

An object of class `power_array`, with attributes `summarized = TRUE`.

Author(s)

Gilles Dutilh

See Also

[PowerGrid](#)

Examples

```

## iterative sse example
sse_pars = list(
  n = seq(from = 10, to = 60, by = 5),
  delta = seq(from = 0.5, to = 1.5, by = 0.2),
  sd = seq(.5, 1.5, .2))

## Define a function that results in TRUE or FALSE for a successful or

```

```
## non-successful (5% significant) simulated trial:
PowFun <- function(n, delta, sd){
  x1 = rnorm(n = n/2, sd = sd)
  x2 = rnorm(n = n/2, mean = delta, sd = sd)
  t.test(x1, x2)$p.value < .05
}

n_iter = 20
powarr = PowerGrid(pars = sse_pars, fun = PowFun,
                   n_iter = n_iter, summarize = FALSE)

dimnames(powarr)
summary(powarr) # indicates that iterations were not
## now summarize
powarr_summarized = SummarizeIterations(powarr, summary_function = mean)
dimnames(powarr_summarized)
summary(powarr_summarized) # indicates that iterations are now summarized
```

summary.power_array *Summary of power_grid object.*

Description

Offers a short summary of the power_array object, summarizing the range of observed values and the grid evaluated across. `##` See PowerGrid for details

Usage

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

Arguments

object	array of class power_grid
...	passed on to cat

Value

nothing

Author(s)

Gilles Dutilh

See Also

[PowerGrid](#)

Examples

```
## Define grid of assumptions to study:
sse_pars = list(
  n = seq(from = 10, to = 50, by = 20),      # sample size
  delta = seq(from = 0.5, to = 1.5, by = 0.5), # effect size
  sd = seq(.1, 1, .3))                      # standard deviation

## Define function that calculates power based on these assumptions:
PowFun <- function(n, delta, sd){
  ptt = power.t.test(n = n/2, delta = delta, sd = sd,
    sig.level = 0.05)
  return(ptt$power)
}

## Evaluate at each combination of assumptions:
powarr = PowerGrid(pars = sse_pars, fun = PowFun, n_iter = NA)
summary(powarr)
```

summary.power_example *Print contents of an example*

Description

Summary method for class power_example.

Usage

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

Arguments

object	object of class power_example
...	passed on to data.frame (which is the thing that is printed)

Details

Print longer informative output for object of class power_example.

Value

nothing

Author(s)

Gilles Dutilh

[.power_array	<i>indexing with [] for class power_array []: R:%20</i>
---------------	---

Description

Method for indexing [] of objects of class power_array. The method makes sure that the resulting array is of class power_array and keeps and updates the object's attributes. These attributes are needed for various functions in the powergrid package to work well. ##' The indexing functions as normal indexing, but note that drop is FALSE by default, so that the resulting array has the same dimensions as the original array. The number of levels at each dimension may be reduced, however. ##'

Usage

```
## S3 method for class 'power_array'
x[... , drop = TRUE]
```

Arguments

x	object
...	index
drop	drop

Value

An array of class power_grid

Author(s)

Gilles Dutilh

See Also

[PowerGrid ArraySlicer](#) for a different method of reducing the dimensions of an array of class power_array.

Examples

```
## Define grid of assumptions to study:
sse_pars = list(
  n = seq(from = 10, to = 50, by = 20),      # sample size
  delta = seq(from = 0.5, to = 1.5, by = 0.5), # effect size
  sd = seq(.1, 1, .3))                      # standard deviation

## Define function that calculates power based on these assumptions:
PowFun <- function(n, delta, sd){
  ptt = power.t.test(n = n/2, delta = delta, sd = sd,
    sig.level = 0.05)
```

```
    return(ptt$power)
}

## Evaluate at each combination of assumptions:
powarr = PowerGrid(pars = sse_pars, fun = PowFun, n_iter = NA)
powarr[2, 1, ] # gives the same as
powarr['30', '0.5', ]
```

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