Package ‘multiverse’

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Title 'Explorable Multiverse' Data Analysis and Reports
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Description Implement 'multiverse' style analyses (Steegen S., Tuerlinckx F, Gelman A., Vanpae- mal, W., 2016)
to show the robustness of statistical inference. 'Multiverse analysis' is a philosophy of statistical reporting where paper authors report the outcomes of many different statistical analyses in order to show how fragile or robust their findings are.
allows users to concisely and flexibly implement 'multiverse-style' analysis, which involve declaring alternate ways of performing an analy- sis step, in R and R Notebooks.
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Description

'multiverse' is an R package that aims to make it easy to declare 'multiverse-style' analysis in R and R notebooks. The 'multiverse' package allows users to concisely and flexibly declare alternate ways of performing an analysis step in order to show how fragile or robust their findings are.
Details

'Multiverse style' analyses (Steegen 2016) is intended to highlight the robustness of an analysis to arbitrary decisions that are present in any data analysis. Considering all possible combinations of reasonable decisions that can be made at each step of an analysis, 'multiverse style' analysis can surface whether an outcome is an artifact of a particular idiosyncratic combination of analysis choices, or if it is robust against such arbitrary choices.

However, current tools do not support declaring 'multiverse' analysis easily, requiring users to declare custom control flows and multiple nested 'if-else' blocks. The 'multiverse' package aims to simplify the process of composing 'multiverse' analysis using a flexible and concise syntax.

To get started with the multiverse package please refer to ‘vignette("branch.Rmd")’, ‘vignette("conditions.Rmd")’ and ‘vignette("multiverse-in-rmd.Rmd")’. For example implementations of analysis using the multiverse package, see the case studies ‘vignette("durante-multiverse-analysis")’ and ‘vignette("hurricane")’.

References


accessors

A multiverse object contains several **Object variables**. These can be accessed using convenient functions. Variables from the analysis that is being performed within the multiverse can be accessed using the `$`. Object variables such as the `code`, the `expanded parameter options table`, the `parameters` and the `conditions` can be accessed using respective functions.

Usage

```r
## S3 method for class 'multiverse'
multiverse$name

## S3 replacement method for class 'multiverse'
multiverse$name <- value

expand(multiverse)

## Default S3 method:
expand(multiverse)

## S3 method for class 'multiverse'
expand(multiverse)

size(multiverse)
```
branch

## Default S3 method:
size(multiverse)

## S3 method for class 'multiverse'
size(multiverse)

code(multiverse)

## Default S3 method:
code(multiverse)

## S3 method for class 'multiverse'
code(multiverse)

parameters(multiverse)

## Default S3 method:
parameters(multiverse)

## S3 method for class 'multiverse'
parameters(multiverse)

conditions(multiverse)

## Default S3 method:
conditions(multiverse)

## S3 method for class 'multiverse'
conditions(multiverse)

extract_variable_from_universe(multiverse, idx, name)

### Arguments

- **multiverse**: Object of class multiverse
- **name**: a variable name
- **value**: a new value to be assigned
- **idx**: index of the universe in the multiverse (corresponds to the row in the table)

### Description

The `branch()` function allows the user to define multiple analysis options for a particular step in the analysis.
Arguments

- parameter: A string to identify the branch. Each branch is characterised using a parameter which takes different options.
- ...: Different options for completing a particular step in the analysis. Each option is declared as `<option_name> ~ <option_calculation>`. See examples for more details.
- .options: Declare a continuous value as the option of a parameter using a sequence (see examples for details), and the expanded sequence will be included as options for that parameter in the multiverse.

Details

For every step in the analysis, there may be more than one analysis option. We use `branch()` to declare these different analysis options. Each branch is characterised by a parameter. The first argument passed into the branch is the parameter.

All the other arguments passed into branch are the different analysis options corresponding to that parameter (that particular step in the analysis process). Naturally, at least two or more options should be declared. Thus, the branch function will provide a warning if the total number arguments passed is less than three.

The `branch()` function does not support nested branches. Thus, we cannot declare a branch within a branch.

Examples

```r
library(dplyr)

# declaring multiple options for a data processing step (calculating a new variable)
data(durante)
data.durante <- durante
data.durante %>%
mutable(ComputedCycleLength = StartDateofLastPeriod - StartDateofPeriodBeforeLast) %>%
mutable(NextMenstrualOnset = StartDateNext)

# create a multiverse object
M <- multiverse()

# if the variable 'NextMenstrualOnset' can be calculated in more than one way
# we can use branch to declare all the different analysis options. This will
# replace the current analysis within the current syntax.
# Since this is a multiverse analysis, this is only supported within a multiverse object. Hence:
inside(M, {
df <- data.durante %>%
mutable(ComputedCycleLength = StartDateofLastPeriod - StartDateofPeriodBeforeLast) %>%
mutable(NextMenstrualOnset = branch(menstrual_calculation),
"mc_option1" ~ StartDateofLastPeriod + ComputedCycleLength,
"mc_option2" ~ StartDateofLastPeriod + ReportedCycleLength,

```
durante

Survey to study the effect of fertility on religiosity and political attitudes

Description

A dataset containing the responses to the survey conducted by Durante, Rae, and Griskevicius (2013) in their study, doi: 10.1177/0956797612466416 The fluctuating female vote: Politics, religion, and the ovulatory cycle. Durante et al. study effect of fertility on religiosity and political attitudes. Steegen, Tuerlinckx, Gelman, and Vanpaemel (2016) used this dataset in their analysis to illustrate how a multiverse analysis can highlight the robustness of the conclusions reached by the original author.

Format

A data frame with 502 rows and 26 variables:

Abortion "Abortion is a women’s [sic] right."
DateTesting Date of participant filling in the questionnaire.
Donate "For the next part of the study we will donate $1 to the presidential campaign of your preferred candidate. Please indicate which candidate’s campaign you would like us to donate $1 to. ” Mitt Romney — Barack Obama"
FreeMarket "In nearly every instance, the free market allocates resources most efficiently."
Marijuana "Marijuana should be legal."
Marriage "Marriage is between a man and a woman."
PrivSocialSec "Privatize Social Security.” 1 – 7
Profit "Business corporations make too much profit."
Rel1 "How much do you believe in God?"
Rel2  "I see myself as a religiously oriented person."
Rel3  "I believe that God or a Higher Power is responsible for my existence"

Relationship What is your current romantic relationship status?" (1) not dating/romantically involved with anyone, (2) dating or involved with only one partner, (3) engaged or living with my partner, (4) married, or (5) other. If participants picked response (5), they were prompted to provide a description of their relationship, which was subsequently coded into one of the four options by the original authors. The data here has already been coded into another response option.

ReportedCycleLength How many days long are your menstrual cycles? (for most women, the range is between 25-35 days) Keep in mind this is the number of days from the start of one menstrual period to the start of the next menstrual period and NOT the length of your menstrual bleeding.

RestrictAbortion "Laws should restrict abortion in all or most cases."
RichTax "The rich should pay a higher tax rate than the middle class."
StLiving "Government should ensure that all citizens meet a certain minimum standard of living"

StartDateNext Indicates the expected start date of their next menstrual period (the research material does not contain a question about the variable. However, the data file for Study 2 contained this variable.)

StartDateofLastPeriod Please give your best estimate of the date on which you started your last period (please be as precise as possible). This date was probably within the last few weeks. Sometimes thinking of where you were when you started your last period helps. For instance, was it on a weekend?, were you at work, was it during a football game?, etc. Please write the date in mm/dd/yyyy format (e.g., 8/18/2012).

StartDateofPeriodBeforeLast Please give your best estimate of the date on which you started the period before your last period (please be as precise as possible). Please write the date in mm/dd/yyyy format (e.g., 7/18/2012)."

StemCell "Stem cell research is moral and can be useful for science."
Sure1 "How sure are you about that date (StartDateofLastPeriod)?"
Sure2 How sure are you about that date (StartDateofPeriodBeforeLast)?

Vote "Imagine walking into the voting booth today. Who would you vote for in the presidential election?" Mitt Romney (republican) – Barack Obama (democrat)"

WorkerID ID of participant

Details

All questions were preceded by the prompt — "Please indicate how much you agree with the following statements"

The following items were responses to religiosity items (on a scale of 1 - 9): Rel1, Rel2, Rel3

The following items were responses to fiscal political attitudes items (on a scale of 1 - 7): RichTax, TooMuchProfit, StandardLiving, FreeMarket, PrivSocialSec

The following items were responses to social political attitudes items (on a scale of 1 - 7): Abortion, Marriage, StemCell, Marijuana, RestrictAbortion
Execute parts of, or the entire multiverse

Description

These are functions which allow the user to execute parts or whole of the multiverse. The user can choose to either execute the default analysis using the `execute_universe`, or a part or whole of the multiverse using the `execute_multiverse`.

Usage

```r
execute_multiverse(multiverse, cores = getOption("mc.cores", 1L))
execute_universe(multiverse, .universe = 1)
```

Arguments

- `multiverse`: The multiverse object
- `cores`: Indicates the number of cores to use. This will execute the entire multiverse in parallel. Defaults to NULL (running in a single core)
- `.universe`: Indicate which universe to execute, if the user wants to execute a specific combination of the parameters using `execute_universe`. Defaults to NULL, which will execute the first (default) analysis.

Details

Each single analysis within the multiverse lives in a separate environment. We provide convenient functions to access the results for the default analysis, as well as parts or whole of the multiverse. Each analysis can also be accessed from the multiverse table, under the results column.

Examples

```r
library(dplyr)
M <- multiverse()
inside(M, {
  data <- rnorm(100, 50, 20)
})
```
extract_variables

x.mean <- mean(data, trim = branch(
  trim.values,
  "trim_none" ~ 0,
  "trim_1pc" ~ 0.05,
  "trim_5pc" ~ 0.025,
  "trim_10pc" ~ 0.05
))
})

# Computes the analysis for all
# universes in the multiverse
M %>%
  execute_multiverse()

extract_variables

Extract variables and objects from the multiverse

Description

This is a wrapper function for extracting one or more variables and objects declared from within the multiverse in a tidy format.

Usage

extract_variables(x, ..., .results = .results)

## S3 method for class 'multiverse'
extract_variables(x, ..., .results = .results)

## S3 method for class 'data.frame'
extract_variables(x, ..., .results = .results)

Arguments

x

either a multiverse object or a dataframe (created using expand) from a multiverse object. See usage.

... one or more variable (or object) names to be extracted from the multiverse object. The names can be quoted or unquoted.

.results (Optional) if the .results column which stores the environments for each unique analysis has been changed, specify the new name of the column. Defaults to `.results`
Details

In a typical analysis, the user will declare variables and objects inside the multiverse object. However, it might be difficult to access the variables and objects, hence we provide convenient wrappers in the form of `extract_variables()`.

If the user wants to extract one or more literals (strings, integers, doubles or logicals of length 1) then each variable is separated out into its own column. If the user wants to extract one or more vectors (or lists) then each such variable will be extracted in its own list column. If the user wants to extract one or more dataframe then they a column of type data frame (or tibble) would be created (which is a special instance of a list column).

Examples

```r
library(dplyr)

M <- multiverse()

inside(M, {
  data <- rnorm(100, 50, 20)

  x.mean <- mean(data, trim = branch(
    trim_values,
    "trim_none" ~ 0,
    "trim_1pc" ~ 0.05,
    "trim_5pc" ~ 0.025,
    "trim_10pc" ~ 0.05
  ))
})

# Extracts the relevant variable from the multiverse
M %>%
  extract_variables(x.mean)

# if you want to filter the multiverse before extracting variables from it
# you ca first create the table and manipulate it before extracting variables
expand(M) %>%
  extract_variables(x.mean)
```

get_code

Code corresponding to a single analysis

Description

Given a particular set of options for each parameter, extracts the code for performing a single analysis from the code used to declare the multiverse. This function is called automatically and not exported.
Usage

```
get_code(.code, .assgn = NULL)
```

Arguments

- `.code` Code that is passed to the multiverse. This is not stripped of calls such as `branch_assert`, which can be done using the `remove_branch_assert` function.
- `.assgn` A list containing the assignments for each defined parameter in the multiverse

Details

For a particular parameter assignment (i.e. one set of options that each defined parameter in the multiverse takes), this function rewrites the code passed into the multiverse to output the corresponding code for that set of parameter values — the analysis for a single universe.

This is primarily going to be called by other functions, and perhaps not going to be as useful to the user for anything other than inspecting the rewritten code.

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**hurricane**

Survey to study the effect of fertility on religiosity and political attitudes

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Description

A dataset for the study conducted by Jung et al. (2014) in their study, doi: 10.1073/pnas.1402786111. *Female hurricanes are deadlier than male hurricanes.*

Format

A data frame with 502 rows and 26 variables:

- **Year** Year in which the hurricane occurred
- **Name** Name given to the hurricane
- **MasFem** A score of how Masculine or Feminine a hurricane is, on a scale of 1 - 11 where 1 is the most masculine and 11 is the most feminine. Each hurricane was rated by 9 independent coders
- **MinPressure_before** The minimum pressure of hurricanes at the time of landfall in the United States obtained from NOAA (www.aoml.noaa.gov/hrd/hurdat/All_U.S._Hurricanes.html)
- **MinPressure_Updated_2014** The minimum pressure of hurricanes at the time of landfall in the United States obtained from NOAA (www.aoml.noaa.gov/hrd/hurdat/All_U.S._Hurricanes.html)
- **Gender_MF** "Marriage is between a man and a woman."
- **Category** Category labels on a scale of 1 - 5, with 5 being the most severe or extreme
- **alldeaths** Total number of deaths caused by the hurricane. Information on death tolls of hurricanes were obtained primarily from monthly weather reports in the digital archive of the National Oceanic and Atmospheric Administration (www.aoml.noaa.gov/hrd/hurdat/mwr_pdf/)
**HighestWindSpeed**  The maximum wind speed of hurricanes at the time of landfall in the United States obtained from NOAA (www.aoml.noaa.gov/hrd/hurdat/All_U.S._Hurricanes.html). This data is only available for storms after 1979

**NDAM** normalized damage (in million $)

**Source**  Source from where the data was gathered

**Elapsed.Yrs**  Time since hurricane

**Details**

This dataset was collated by Jung et. al in their study *Female hurricanes are deadlier than male hurricanes* They hypothesised that hurricanes with more feminine names might be perceived as less dangerous and hence lead to people taking fewer precautionary measures, resulting in more death and damages.

**References**


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**inside**

---

**Description**

Add code to the multiverse using the function using a function call, or an assignment operator, which is a wrapper around the function

**Usage**

```r
inside(multiverse, .expr, .label = NULL)
```

**Arguments**

- `multiverse`  A multiverse object. A multiverse object is an S3 object which can be defined using `multiverse()`
- `expr`  R syntax. All the operations that the user wants to perform within the multiverse can be passed. Since it accepts a single argument, chunks of code can be passed using `. See example for details.
- `label`  It is extracted automatically from the code block of type `multiverse` when run in an RMarkdown document. This should be used only within an RMarkdown document. Defaults to NULL.
Details

The `inside` function can only access variables which can be accessed at the same environment where the multiverse object was declared in.

To perform a multiverse analysis, we will need to write code to be executed within the multiverse. The `inside()` function allows us to do this. Use `inside()` to pass any code to the specified multiverse, which is captured as an expression. To define multiple analysis options in the code passed to the multiverse, use the `branch()` function. See `branch` for more details on how to declare multiple analysis options.

The `inside` function only stores the code, and does not execute any code at this step. To execute, we provide separate functions. See `execute` for executing the code.

Instead of using the `inside()` function, an alternate implementation of the multiverse is using the assignment operator, `<-`. See examples below.

**Note:** the `inside()` function can only access variables which can be accessed at the same level as the multiverse object. Since `inside()` is merely an interface to add analysis to the multiverse object, even if it is being called by another function, it is actually manipulating the multiverse object, which will have a different parent environment from where `inside()` is called, and hence not have access to variables which might be accessible in the environment within the function from where `inside()` is called.

Value

a multiverse object

Examples

```r
M.1 <- multiverse()

# using `inside` to declare multiverse code
inside(M.1, {
  data <- rnorm(100, 50, 20)

  x.mean <- mean(data, trim = branch(
    trim_values,
    "trim_none" ~ 0,
    "trim_1pc" ~ 0.05,
    "trim_5pc" ~ 0.025,
    "trim_10pc" ~ 0.05
  ))
})

M.2 <- multiverse()

# using the assignment operator to declare multiverse code
inside(M.2, {
  data <- rnorm(100, 50, 20)
})

inside(M.2, {
```
# declaring multiple options for a data processing step (calculating a new variable)
data(durante)
df <- durante

inside(M.1, {
  df <- df %>%
  mutate( ComputedCycleLength = StartDateofLastPeriod - StartDateofPeriodBeforeLast ) %>%
  mutate( NextMenstrualOnset = branch(menstrual_calculation,
    "mc_option1" ~ StartDateofLastPeriod + ComputedCycleLength,
    "mc_option2" ~ StartDateofLastPeriod + ReportedCycleLength,
    "mc_option3" ~ StartDateNext
  )
})

---

## Description

An easier way to interact with a multiverse object by using a custom code block

## Details

This is a custom code block that allows the users to interface directly with a created multiverse object. This allows users to implement analysis in RMarkdown without using auxiliary functions such as `inside`. However, `inside` is still required to define and execute multiverse analyses in an RScript using this package. See examples for more details.

In RStudio, you can create a shortcut for this using RStudio addins (we recommend ‘Cmd + Opt + M’ in Mac and ‘Ctrl + Alt + M’ in Windows). To add a shortcut, go to Tools > AddIns > Browse AddIns... > Keyboard shortcuts. Search for ‘insert multiverse code chunk’ and add a keyboard shortcut to this function. Once you have set this up, the keyboard shortcut will create a code block in any RMarkdown document.
multiverse

**Code Block Options**

The multiverse code blocks require two named arguments:

1. label: this is a unique identifier for each code block. If the same label is used for two different code blocks, the code associated with the previous block in the multiverse will be overwritten by the subsequent one. If a code block is created using the keyboard shortcut, it will auto-generate a (unique) label

2. inside: the multiverse object this code block will be associated with. Defaults to "M"

**Examples**

```r
## Not run:
# Typically R users, using RMarkdown could specify code by creating a code block,
# and use the functions provided to add code to the multiverse:
```
```r
M = multiverse()
inside(M, { df = data.frame( x = 1:10 ) })
```

# Here, they would need to reference the multiverse object 
# every time they want to add anything to it.
# Instead, they could add code to the multiverse by using a custom code engine:

```r
## End(Not run)
```

---

**multiverse**  
*Create a new multiverse object*

**Description**

Constructs a new multiverse object which enables conducting a multiverse analysis

This function returns ‘TRUE’ for objects of class multiverse, and ‘FALSE’ for all other objects.

**Usage**

```r
multiverse(...)
```

```r
is_multiverse(x)
```

```r
is.multiverse(x)
```
Arguments

... currently unused
x An object

Details

To perform a multiverse analysis, the user needs to first construct a new multiverse object. The user can declare multiple analysis pathways within this multiverse object, and execute these analyses. The multiverse object contains the following slots:

- code: This slot stores the user’s code for conducting a multiverse analysis. The user can define multiple analysis pathways at each step in the analysis using the ‘branch’ call. It supports tidyverse syntax.

- parameters: This slot contains a named list of lists. It contains each parameter defined in the code using the ‘branch()’ function, and the options defined for each parameter (as a list).

- conditions (NOT IMPLEMENTED): This slot contains a list of conditions: if any of the parameter values are conditional on a specific value of another parameter, these can be defined in the code using ‘branch_assert()’ or ‘branch_exclude()’.

- currentParameter_assignment: This slot is a list which contains a single option assigned for each parameter defined in the ‘code’.

- multiverse_table: This slot contains a table (in implementation, a tibble which is a rectangular data structure) where each column of the table will be a unique parameter. The table will contain every possible combination of options for each parameter — the number of rows corresponds to the number of different analysis paths. The table also contains, for each row, a list of option assignments for each parameter (‘parameter_assignment’ column), code for executing that particular analysis (of type ‘expression’), and environments where each code will be executed.

Value

An empty multiverse object

‘TRUE’ if the object inherits from the ‘multiverse’ class.
‘TRUE’ if the object inherits from the ‘multiverse’ class.

Examples

M <- multiverse()
**parse_multiverse**

*Parse the multiverse syntax to identify branches*

**Description**

In a multiverse, the user can define different values that a parameter can take using the ‘branch’ call. The ‘parse_multiverse’ identifies the ‘branch’ calls defined in the analysis syntax and parses them into a list of parameters and the corresponding values that each parameter can take. This function is called automatically and not exported.

**Usage**

```r
parse_multiverse(.multiverse, .expr, .code, .label)
```

**Arguments**

- `.multiverse` The multiverse object which will contain the analysis
- `.expr` The expression that is being parsed
- `.code` All the code that has been passed to the multiverse
- `.label` The label of the code block or inside call which was used to pass the code being parsed into the multiverse

**Value**

The ‘parse_multiverse’ function returns a list of lists. the list of parameters and the list of conditions. The list of parameters is a named list which defines all the values that each defined parameter can take. The list of conditions defines, if any of the parameter values are conditional on a specific value of another parameter, the condition.

**print**

*Accessing contents of the multiverse object*

**Description**

prints objects of class multiverse. Provides a quick overview of the multiverse by listing the parameters and conditions declared, to get an overview of the number of combinations. The function outputs upto 20 of the parameters declared along with their option names (upto 5), and upto 10 of the conditions declared.

**Usage**

```r
## S3 method for class 'multiverse'
print(x, ...)
```
Arguments

x An object of class multiverse
.
.
. further arguments passed to or from other methods. Currently ignored.

Description

Data collected by Jansen et al. in their study, doi: 10.1145/2470654.2481359 Evaluating the Efficiency of Physical Visualizations which investigated factors contributing to the efficiency of physical visualizations.

Format

A data frame with 512 observations and 19 variables:

subject Subject identifier
group Group / experiment session number in which the participant was involved in the experiment
formerSubject Yes/No. Whether subject had participated in a previous experiment conducted by Jansen et al.
conditionrank
modalityname Name of the modality of interaction. One of "Virtual Mouse", "Virtual prop", "Physical touch", "Physical no-touch"
repetition 1/2. Whether the participant was interacting with the visualization for the first time. Participants interacted with visualizations of two different datasets and this variable stores the order.
modality Index of the modality of interaction
question Index of question asked to the participant as part of the experiment. Each participant was asked 4 questions. All questions involved a comparison task.
trial Each participant performed 32 trials. Participants answered 4 questions for 8 different datasets which resulted in 32 trials per participant.
datasetname Each participant was presented with 8 different datasets through the visualizations. These were: "army", "carmortality", "education", "externaldebt", "grosscapital", "health", "hiv", "military"
readingTime Time taken by participant to read the visualization in seconds
error If the question was answered correctly by the participants.
duration If the question was answered correctly by the participants.
perceivedDifficulty Self reported perceived difficulty of the task by each participant.
perceivedTime Self reported perceived time taken to perform the task by each participant.
vis_correlation

References


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vis_correlation  
Participants responses in the study by Harrison et al., "Ranking Visualizations of correlation according to Weber’s law”

Description

A dataset containing the aggregated responses of the participants. In this study, participants were asked to make multiple judgements about the correlation.

Format

A data frame with 502 rows and 26 variables:

- **participant**  Participant identifier
- **vis** Type of visualization used
- **rdirection** The direction of the slope of the line (positive or negative)
- **sign** The direction of the slope of the line (1 or -1)
- **visandsign** A combination variable of visualization type and rdirection
- **rbase** The coefficient of correlation using which the stimuli was generated
- **approach** NA
- **jnd** Estimated JND value for that participant
- **condition** Condition that the participant was placed in (which is a combination of vis, rbase and approach)

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