

# Package ‘ferrn’

May 8, 2026

**Title** Facilitate Exploration of touRR optimisation

**Version** 0.3.0

**Description** Diagnostic plots for optimisation, with a focus on projection pursuit. These show paths the optimiser takes in the high-dimensional space in multiple ways: by reducing the dimension using principal component analysis, and also using the tour to show the path on the high-dimensional space. Several botanical colour palettes are included, reflecting the name of the package. A paper describing the methodology can be found at <https://journal.r-project.org/articles/RJ-2021-105/index.html>.

**License** MIT + file LICENSE

**Encoding** UTF-8

**LazyData** true

**URL** <https://github.com/huizezhang-sherry/ferrn/>,  
<https://huizezhang-sherry.github.io/ferrn/>

**BugReports** <https://github.com/huizezhang-sherry/ferrn/issues>

**Imports** rlang (>= 0.1.2), dplyr, magrittr, scales, gganimate, ggplot2,  
tibble, purrr, tourr, stringr, ggrepel, ggforce, tidyr, cli,  
progress, glue, GpGp

**RoxygenNote** 7.3.3

**Depends** R (>= 4.1.0)

**Suggests** roxygen2, covr, pkgdown, testthat, forcats, patchwork,  
future.apply, ash, vdiff

**Language** en-GB

**NeedsCompilation** no

**Author** H. Sherry Zhang [aut, cre] (ORCID:  
<https://orcid.org/0000-0002-7122-1463>),  
Dianne Cook [aut] (ORCID: <https://orcid.org/0000-0002-3813-7155>),  
Ursula Laa [aut] (ORCID: <https://orcid.org/0000-0002-0249-6439>),  
Nicolas Langrené [aut] (ORCID: <https://orcid.org/0000-0001-7601-4618>),  
Patricia Menéndez [aut] (ORCID:  
<https://orcid.org/0000-0003-0701-6315>)

**Maintainer** H. Sherry Zhang <huizezhangsh@gmail.com>

**Repository** CRAN

**Date/Publication** 2025-11-20 22:10:10 UTC

## Contents

add_anchor . . . . .	3
add_anno . . . . .	3
add_dir_search . . . . .	4
add_end . . . . .	5
add_interp . . . . .	5
add_interp_last . . . . .	6
add_interrupt . . . . .	7
add_search . . . . .	8
add_space . . . . .	9
add_start . . . . .	10
add_theo . . . . .	11
bind_random . . . . .	12
bind_random_matrix . . . . .	12
bind_theoretical . . . . .	13
botanical_palettes . . . . .	14
clean_method . . . . .	15
explore_space_start . . . . .	15
explore_space_tour . . . . .	17
explore_trace_interp . . . . .	18
explore_trace_search . . . . .	19
flip_sign . . . . .	20
format_label . . . . .	21
get_best . . . . .	22
holes_1d_geo . . . . .	24
plot_projection . . . . .	25
sample_bases . . . . .	26
scale_color_continuous_botanical . . . . .	28
sine1000 . . . . .	29
StatHuber . . . . .	30
theme_fern . . . . .	35

**Index**

**36**

---

add_anchor	<i>A ggproto for drawing anchor points</i>
------------	--

---

**Description**

This is a wrapper function used by `explore_space_pca()` and should be called directly by the user

**Usage**

```
add_anchor(dt, anchor_size = 3, anchor_alpha = 0.5, anchor_color = NULL, ...)
```

**Arguments**

<code>dt</code>	A data object from the running the optimisation algorithm in guided tour
<code>anchor_size</code>	numeric; the size of the anchor points
<code>anchor_alpha</code>	numeric; the alpha of the anchor points
<code>anchor_color</code>	the variable to be coloured by
<code>...</code>	other aesthetics inherent from <code>explore_space_pca()</code>

**Value**

a wrapper for drawing anchor points in `explore_space_pca()`

**See Also**

Other draw functions: [add\\_anno\(\)](#), [add\\_dir\\_search\(\)](#), [add\\_end\(\)](#), [add\\_interp\(\)](#), [add\\_interp\\_last\(\)](#), [add\\_interrupt\(\)](#), [add\\_search\(\)](#), [add\\_space\(\)](#), [add\\_start\(\)](#), [add\\_theo\(\)](#)

---

add_anno	<i>A ggproto for annotating the symmetry of the starting points</i>
----------	---

---

**Description**

This is a wrapper function used by `explore_space_pca()` and should be called directly by the user

**Usage**

```
add_anno(dt, anno_color = "black", anno_lty = "dashed", anno_alpha = 0.1, ...)
```

**Arguments**

dt	A data object from the running the optimisation algorithm in guided tour
anno_color	character; the colour of the annotation line
anno_lty	character; the linetype of the annotation line
anno_alpha	numeric; the alpha of the annotation line
...	other aesthetics inherent from <code>explore_space_pca()</code>

**Value**

a wrapper for annotating the symmetry of start points in `explore_space_pca()`

**See Also**

Other draw functions: [add\\_anchor\(\)](#), [add\\_dir\\_search\(\)](#), [add\\_end\(\)](#), [add\\_interp\(\)](#), [add\\_interp\\_last\(\)](#), [add\\_interrupt\(\)](#), [add\\_search\(\)](#), [add\\_space\(\)](#), [add\\_start\(\)](#), [add\\_theo\(\)](#)

---

add_dir_search	<i>A ggproto for drawing directional search points</i>
----------------	--

---

**Description**

This is a wrapper function used by `explore_space_pca()` and should be called directly by the user

**Usage**

```
add_dir_search(dt, dir_size = 0.5, dir_alpha = 0.5, dir_color = NULL, ...)
```

**Arguments**

dt	A data object from the running the optimisation algorithm in guided tour
dir_size	numeric; the size of the directional search points in pseudo derivative search
dir_alpha	numeric; the alpha of the directional search points in pseudo derivative search
dir_color	the variable to be coloured by
...	other aesthetics inherent from <code>explore_space_pca()</code>

**Value**

a wrapper for drawing directional search points (used in pseudo derivative search) with buffer in `explore_space_pca()`

**See Also**

Other draw functions: [add\\_anchor\(\)](#), [add\\_anno\(\)](#), [add\\_end\(\)](#), [add\\_interp\(\)](#), [add\\_interp\\_last\(\)](#), [add\\_interrupt\(\)](#), [add\\_search\(\)](#), [add\\_space\(\)](#), [add\\_start\(\)](#), [add\\_theo\(\)](#)

---

add\_end *A ggproto for drawing start points*

---

### Description

This is a wrapper function used by `explore_space_pca()` and should be called directly by the user

### Usage

```
add_end(dt, end_size = 5, end_alpha = 1, end_color = NULL, ...)
```

### Arguments

<code>dt</code>	A data object from the running the optimisation algorithm in guided tour
<code>end_size</code>	numeric; the size of the end point
<code>end_alpha</code>	numeric; the alpha of the end point
<code>end_color</code>	the variable to be coloured by
<code>...</code>	other aesthetics inherent from <code>explore_space_pca()</code>

### Value

a wrapper for drawing end points in `explore_space_pca()`

### See Also

Other draw functions: [add\\_anchor\(\)](#), [add\\_anno\(\)](#), [add\\_dir\\_search\(\)](#), [add\\_interp\(\)](#), [add\\_interp\\_last\(\)](#), [add\\_interrupt\(\)](#), [add\\_search\(\)](#), [add\\_space\(\)](#), [add\\_start\(\)](#), [add\\_theo\(\)](#)

---

add\_interp *A ggproto for drawing interpolation path*

---

### Description

This is a wrapper function used by `explore_space_pca()` and should be called directly by the user

### Usage

```
add_interp(
  dt,
  interp_size = 1.5,
  interp_alpha = NULL,
  interp_color = NULL,
  interp_group = NULL,
  ...
)
```

**Arguments**

dt                    A data object from the running the optimisation algorithm in guided tour  
 interp\_size          numeric; the size of the interpolation path  
 interp\_alpha        numeric; the alpha of the interpolation path  
 interp\_color        the variable to be coloured by  
 interp\_group        the variable to label different interpolation path  
 ...                   other aesthetics inherent from `explore_space_pca()`

**Value**

a wrapper for drawing the interpolation points in `explore_space_pca()`

**See Also**

Other draw functions: [add\\_anchor\(\)](#), [add\\_anno\(\)](#), [add\\_dir\\_search\(\)](#), [add\\_end\(\)](#), [add\\_interp\\_last\(\)](#), [add\\_interrupt\(\)](#), [add\\_search\(\)](#), [add\\_space\(\)](#), [add\\_start\(\)](#), [add\\_theo\(\)](#)

---

add\_interp\_last            *A ggproto for drawing finish points*

---

**Description**

This is a wrapper function used by `explore_space_pca()` and should be called directly by the user

**Usage**

```
add_interp_last(
  dt,
  interp_last_size = 3,
  interp_last_alpha = 1,
  interp_last_color = NULL,
  ...
)
```

**Arguments**

dt                    A data object from the running the optimisation algorithm in guided tour  
 interp\_last\_size     numeric; the size of the last interpolation points in each iteration  
 interp\_last\_alpha    numeric; the alpha of the last interpolation points in each iteration  
 interp\_last\_color    the variable to be coloured by  
 ...                   other aesthetics inherent from `explore_space_pca()`

**Value**

a wrapper for drawing the last interpolation points of each iteration in `explore_space_pca()`

**See Also**

Other draw functions: `add_anchor()`, `add_anno()`, `add_dir_search()`, `add_end()`, `add_interp()`, `add_interrupt()`, `add_search()`, `add_space()`, `add_start()`, `add_theo()`

---

add_interrupt	<i>A ggproto for annotating the interrupted path</i>
---------------	--

---

**Description**

This is a wrapper function used by `explore_space_pca()` and should be called directly by the user

**Usage**

```
add_interrupt(
  dt,
  interrupt_size = 0.5,
  interrupt_alpha = NULL,
  interrupt_color = NULL,
  interrupt_group = NULL,
  interrupt_linetype = "dashed",
  ...
)
```

**Arguments**

<code>dt</code>	A data object from the running the optimisation algorithm in guided tour
<code>interrupt_size</code>	numeric; the size of the interruption path
<code>interrupt_alpha</code>	numeric; the alpha of the interruption path
<code>interrupt_color</code>	the variable to be coloured by
<code>interrupt_group</code>	the variable to label different interruption
<code>interrupt_linetype</code>	character; the linetype to annotate the interruption
<code>...</code>	other aesthetics inherent from <code>explore_space_pca()</code>

**Value**

a wrapper for annotating the interruption in `explore_space_pca()`

**See Also**

Other draw functions: [add\\_anchor\(\)](#), [add\\_anno\(\)](#), [add\\_dir\\_search\(\)](#), [add\\_end\(\)](#), [add\\_interp\(\)](#), [add\\_interp\\_last\(\)](#), [add\\_search\(\)](#), [add\\_space\(\)](#), [add\\_start\(\)](#), [add\\_theo\(\)](#)

---

add_search	<i>A ggproto for drawing search points</i>
------------	--

---

**Description**

This is a wrapper function used by `explore_space_pca()` and should be called directly by the user

**Usage**

```
add_search(dt, search_size = 0.5, search_alpha = 0.5, search_color = NULL, ...)
```

**Arguments**

dt	A data object from the running the optimisation algorithm in guided tour
search_size	numeric; the size of the search points
search_alpha	numeric; the alpha of the anchor points
search_color	the variable to be coloured by
...	other aesthetics inherent from <code>explore_space_pca()</code>

**Value**

a wrapper for drawing search points in `explore_space_pca()`

**See Also**

Other draw functions: [add\\_anchor\(\)](#), [add\\_anno\(\)](#), [add\\_dir\\_search\(\)](#), [add\\_end\(\)](#), [add\\_interp\(\)](#), [add\\_interp\\_last\(\)](#), [add\\_interrupt\(\)](#), [add\\_space\(\)](#), [add\\_start\(\)](#), [add\\_theo\(\)](#)

---

`add_space`*A ggproto for drawing circle*

---

### Description

This is a wrapper function used by `explore_space_pca()` and should be called directly by the user

### Usage

```
add_space(  
  dt,  
  space_alpha = 0.5,  
  space_fill = "grey92",  
  space_color = "white",  
  cent_size = 1,  
  cent_alpha = 1,  
  cent_color = "black",  
  ...  
)
```

### Arguments

<code>dt</code>	A data object from the running the optimisation algorithm in guided tour
<code>space_alpha</code>	numeric; the alpha of the basis space
<code>space_fill</code>	character; the colour of the space filling
<code>space_color</code>	character; the colour of the space brim
<code>cent_size</code>	numeric; the size of the centre point
<code>cent_alpha</code>	numeric; an alpha of the centre point
<code>cent_color</code>	character; the colour of the centre point
<code>...</code>	other aesthetics inherent from <code>explore_space_pca()</code>

### Value

a wrapper for drawing the space in `explore_space_pca()`

### See Also

Other draw functions: [add\\_anchor\(\)](#), [add\\_anno\(\)](#), [add\\_dir\\_search\(\)](#), [add\\_end\(\)](#), [add\\_interp\(\)](#), [add\\_interp\\_last\(\)](#), [add\\_interrupt\(\)](#), [add\\_search\(\)](#), [add\\_start\(\)](#), [add\\_theo\(\)](#)

**Examples**

```
library(ggplot2)
space <- tibble::tibble(x0 = 0, y0 = 0, r = 5)
ggplot() +
  add_space(space) +
  theme_void() +
  theme(aspect.ratio = 1)
```

---

 add\_start

*A ggproto for drawing start points*


---

**Description**

This is a wrapper function used by `explore_space_pca()` and should be called directly by the user

**Usage**

```
add_start(dt, start_size = 5, start_alpha = 1, start_color = NULL, ...)
```

**Arguments**

<code>dt</code>	A data object from the running the optimisation algorithm in guided tour
<code>start_size</code>	numeric; the size of start point
<code>start_alpha</code>	numeric; the alpha of start point
<code>start_color</code>	the variable to be coloured by
<code>...</code>	other aesthetics inherent from <code>explore_space_pca()</code>

**Value**

a wrapper for drawing start points in `explore_space_pca()`

**See Also**

Other draw functions: [add\\_anchor\(\)](#), [add\\_anno\(\)](#), [add\\_dir\\_search\(\)](#), [add\\_end\(\)](#), [add\\_interop\(\)](#), [add\\_interop\\_last\(\)](#), [add\\_interrupt\(\)](#), [add\\_search\(\)](#), [add\\_space\(\)](#), [add\\_theo\(\)](#)

**Examples**

```
library(ggplot2)
# construct the space and start df for plotting
space <- tibble::tibble(x0 = 0, y0 = 0, r = 5)
holes_1d_geo %>%
  compute_pca() %>%
  purrr::pluck("aug") %>%
  clean_method() %>%
  get_start()
```

---

add_theo	<i>A ggproto for drawing the theoretical basis, if applicable</i>
----------	---

---

### Description

This is a wrapper function used by `explore_space_pca()` and should be called directly by the user

### Usage

```
add_theo(  
  dt,  
  theo_label = "*",  
  theo_size = 25,  
  theo_alpha = 0.8,  
  theo_color = "#000000",  
  ...  
)
```

### Arguments

<code>dt</code>	A data object from the running the optimisation algorithm in guided tour
<code>theo_label</code>	character; a symbol to label the theoretical point
<code>theo_size</code>	numeric; the size of the theoretical point
<code>theo_alpha</code>	numeric; the alpha of the theoretical point
<code>theo_color</code>	character; the colour of the theoretical point in hex
<code>...</code>	other aesthetics inherent from <code>explore_space_pca()</code>

### Value

a wrapper for drawing theoretical points in `explore_space_pca()`

### See Also

Other draw functions: [add\\_anchor\(\)](#), [add\\_anno\(\)](#), [add\\_dir\\_search\(\)](#), [add\\_end\(\)](#), [add\\_interp\(\)](#), [add\\_interp\\_last\(\)](#), [add\\_interrupt\(\)](#), [add\\_search\(\)](#), [add\\_space\(\)](#), [add\\_start\(\)](#)

---

bind_random	<i>Bind random bases in the projection bases space</i>
-------------	--

---

### Description

Given the orthonormality constraint, the projection bases live in a high dimensional hollow sphere. Generating random points on the sphere is useful to perceive the data object in the high dimensional space.

### Usage

```
bind_random(dt, n = 500, seed = 1)
```

### Arguments

dt	a data object collected by the projection pursuit guided tour optimisation in the tourr package
n	numeric; the number of random bases to generate in each dimension by geozoo
seed	numeric; a seed for generating reproducible random bases from geozoo

### Value

a tibble object containing both the searched and random bases

### See Also

Other bind: [bind\\_random\\_matrix\(\)](#), [bind\\_theoretical\(\)](#)

### Examples

```
bind_random(holes_1d_better) %>% tail(5)
```

---

bind_random_matrix	<i>Bind random bases in the projection bases space as a matrix</i>
--------------------	--

---

### Description

Bind random bases in the projection bases space as a matrix

### Usage

```
bind_random_matrix(basis, n = 500, d = 1, front = FALSE, seed = 1)
```

**Arguments**

basis	a matrix returned by <code>get_basis_matrix()</code>
n	numeric; the number of random bases to generate in each dimension by <code>geozoo</code>
d	numeric; dimension of the basis, $d = 1, 2, \dots$
front	logical; if the random bases should be bound before or after the original bases
seed	numeric; a seed for generating reproducible random bases from <code>geozoo</code>

**Value**

matrix  
a matrix containing both the searched and random bases

**See Also**

Other bind: [bind\\_random\(\)](#), [bind\\_theoretical\(\)](#)

**Examples**

```
data <- get_basis_matrix(holes_1d_geo)
bind_random_matrix(data) %>% tail(5)
```

---

bind_theoretical	<i>Bind the theoretical best record</i>
------------------	---

---

**Description**

The theoretical best basis is usually known for a simulated problem. Augment this information into the data object allows for evaluating the performance of optimisation against the theory.

**Usage**

```
bind_theoretical(dt, matrix, index, raw_data)
```

**Arguments**

dt	a data object collected by the projection pursuit guided tour optimisation in the <code>tourr</code> package
matrix	a matrix of the theoretical basis
index	the index function used to calculate the index value
raw_data	a tibble of the original data used to calculate the index value

**Value**

a tibble object containing both the searched and theoretical best bases

**See Also**

Other bind: `bind_random()`, `bind_random_matrix()`

**Examples**

```
best <- matrix(c(0, 1, 0, 0, 0), nrow = 5)
tail(holes_1d_better %>% bind_theoretical(best, tourr::holes(), raw_data = boa5), 1)
```

---

botanical\_palettes      *A customised colour palette based on Australian botanies*

---

**Description**

Available colours in the palettes

**Usage**

```
botanical_palettes

botanical_pal(palette = "fern", reverse = FALSE)
```

**Arguments**

palette	Colour palette from the botanical_palette
reverse	logical, if the colour should be reversed

**Format**

An object of class `list` of length 5.

**Value**

a function for interpolating colour in the botanical palette

---

clean_method	<i>Clean method names</i>
--------------	---------------------------

---

**Description**

Clean method names

**Usage**

```
clean_method(dt)
```

**Arguments**

dt                    a data object

**Value**

a tibble with method cleaned

**Examples**

```
head(clean_method(holes_1d_better), 5)
```

---

explore_space_start	<i>Plot the PCA projection of the projection bases space</i>
---------------------	--

---

**Description**

Plot the PCA projection of the projection bases space

**Usage**

```
explore_space_start(dt, group = NULL, pca = TRUE, ...)
```

```
explore_space_end(dt, group = NULL, pca = TRUE, ...)
```

```
explore_space_pca(  
  dt,  
  details = FALSE,  
  pca = TRUE,  
  group = NULL,  
  color = NULL,  
  facet = NULL,  
  ...,  
  animate = FALSE  
)
```

**Arguments**

dt	a data object collected by the projection pursuit guided tour optimisation in <code>tourr</code>
group	the variable to label different runs of the optimiser(s)
pca	logical; if PCA coordinates need to be computed for the data
...	other arguments passed to <code>add_*()</code> functions
details	logical; if components other than start, end and interpolation need to be shown
color	the variable to be coloured by
facet	the variable to be faceted by
animate	logical; if the interpolation path needs to be animated

**Value**

a `ggplot2` object

**See Also**

Other main plot functions: [explore\\_space\\_tour\(\)](#), [explore\\_trace\\_interp\(\)](#), [explore\\_trace\\_search\(\)](#)

**Examples**

```
dplyr::bind_rows(holes_1d_geo, holes_1d_better) %>%
  bind_theoretical(matrix(c(0, 1, 0, 0, 0), nrow = 5),
    index = tourr::holes(), raw_data = boa5
  ) %>%
  explore_space_pca(group = method, details = TRUE) +
  scale_color_discrete_botanical()

## Not run:
best <- matrix(c(0, 1, 0, 0, 0), nrow = 5)
dt <- bind_theoretical(holes_1d_jellyfish, best, tourr::holes(), raw_data = boa5)
explore_space_start(dt)
explore_space_end(dt, group = loop, theo_size = 10, theo_color = "#FF0000")
explore_space_pca(
  dt, facet = loop, interp_size = 0.5, theo_size = 10,
  start_size = 1, end_size = 3
)

## End(Not run)
```

---

explore\_space\_tour      *Plot the grand tour animation of the bases space in high dimension*

---

### Description

Plot the grand tour animation of the bases space in high dimension

### Usage

```
explore_space_tour(..., axes = "bottomleft")

prep_space_tour(
  dt,
  group = NULL,
  flip = FALSE,
  n_random = 2000,
  color = NULL,
  rand_size = 1,
  rand_color = "#D3D3D3",
  point_size = 1.5,
  end_size = 5,
  theo_size = 3,
  theo_shape = 17,
  theo_color = "black",
  palette = botanical_palettes$fern,
  ...
)
```

### Arguments

...	other argument passed to <code>tourr::animate_xy()</code> and <code>prep_space_tour()</code>
axes	see <code>[tourr::animate_xy()]</code>
dt	a data object collected by the projection pursuit guided tour optimisation in <code>tourr</code>
group	the variable to label different runs of the optimiser(s)
flip	logical; if the sign flipping need to be performed
n_random	numeric; the number of random basis to generate
color	the variable to be coloured by
rand_size	numeric; the size of random points
rand_color	character; the color hex code for random points
point_size	numeric; the size of points searched by the optimiser(s)
end_size	numeric; the size of end points
theo_size	numeric; the size of theoretical point(s)

theo\_shape      numeric; the shape symbol in the basic plot  
 theo\_color      character; the color of theoretical point(s)  
 palette          the colour palette to be used

### Value

explore\_space\_tour() an animation of the search path in the high-dimensional sphere  
 prep\_space\_tour() a list containing various components needed for producing the animation

### See Also

Other main plot functions: [explore\\_space\\_start\(\)](#), [explore\\_trace\\_interp\(\)](#), [explore\\_trace\\_search\(\)](#)

### Examples

```
if (FALSE){
  explore_space_tour(dplyr::bind_rows(holes_1d_better, holes_1d_geo),
    group = method, palette = botanical_palettes$fern[c(1, 6)]
  )
}
```

---

explore\_trace\_interp    *Plot the trace the search progression*

---

### Description

Trace the index value of search/ interpolation points in guided tour optimisation

### Usage

```
explore_trace_interp(
  dt,
  iter = NULL,
  color = NULL,
  group = NULL,
  cutoff = 50,
  target_size = 3,
  interp_size = 1,
  accuracy_x = 5,
  accuracy_y = 0.01
)
```

**Arguments**

dt	a data object collected by the projection pursuit guided tour optimisation in <code>tourr</code>
iter	the variable to be plotted on the x-axis
color	the variable to be coloured by
group	the variable to label different runs of the optimiser(s)
cutoff	numeric; if the number of interpolating points is smaller than <code>cutoff</code> , all the interpolation points will be plotted as dots
target_size	numeric; the size of target points in the interpolation
interp_size	numeric; the size of interpolation points
accuracy_x	numeric; If the difference of two neighbour x-labels is smaller than <code>accuracy_x</code> , only one of them will be displayed. Used for better axis label
accuracy_y	numeric; the precision of y-axis label

**Value**

a ggplot object for diagnosing how the index value progresses during the interpolation

**See Also**

Other main plot functions: [explore\\_space\\_start\(\)](#), [explore\\_space\\_tour\(\)](#), [explore\\_trace\\_search\(\)](#)

**Examples**

```
# Compare the trace of interpolated points in two algorithms
holes_1d_better %>%
  explore_trace_interp(interp_size = 2) +
  scale_color_continuous_botanical(palette = "fern")
```

---

`explore_trace_search` *Plot the count in each iteration*

---

**Description**

Plot the count in each iteration

**Usage**

```
explore_trace_search(
  dt,
  iter = NULL,
  color = NULL,
  cutoff = 15,
  extend_lower = 0.95,
  ...
)
```

**Arguments**

dt	a data object collected by the projection pursuit guided tour optimisation in tourr
iter	the variable to be plotted on the x-axis
color	the variable to be coloured by
cutoff	numeric; if the number of searches in one iteration is smaller than cutoff, a point geom, rather than boxplot geom, will be used.
extend_lower	a numeric for extending the y-axis to display text labels
...	arguments passed into geom_label_repel() for displaying text labels

**Value**

a ggplot object for diagnosing how many points the optimiser(s) have searched

**See Also**

Other main plot functions: [explore\\_space\\_start\(\)](#), [explore\\_space\\_tour\(\)](#), [explore\\_trace\\_interp\(\)](#)

**Examples**

```
# Summary plots for search points in two algorithms
library(patchwork)
library(dplyr)
library(ggplot2)
p1 <- holes_1d_better %>% explore_trace_search() +
  scale_color_continuous_botanical(palette = "fern")
p2 <- holes_2d_better_max_tries %>% explore_trace_search() +
  scale_color_continuous_botanical(palette = "daisy")
p1 / p2
```

---

 flip\_sign

*Helper functions for 'explore\_space\_pca()'*


---

**Description**

Helper functions for 'explore\_space\_pca()'

**Usage**

```
flip_sign(dt, group = NULL, ...)
```

```
compute_pca(dt, group = NULL, random = TRUE, flip = TRUE, ...)
```

**Arguments**

dt	a data object collected by the projection pursuit guided tour optimisation in tourr
group	the variable to label different runs of the optimiser(s)
...	other arguments received from explore_space_pca()
random	logical; if random bases from the basis space need to be added to the data
flip	logical; if the sign flipping need to be performed

**Value**

flip\_sign(): a list containing a matrix of all the bases, a logical value indicating whether a flip of sign is performed, and a data frame of the original dataset.

compute\_pca(): a list containing the PCA summary and a data frame with PC coordinates augmented.

**Examples**

```
dt <- dplyr::bind_rows(holes_1d_geo, holes_1d_better)
flip_sign(dt, group = method) %>% str(max = 1)
compute_pca(dt, group = method)
```

---

format\_label

*Better label formatting to avoid overlapping*


---

**Description**

Better label formatting to avoid overlapping

**Usage**

```
format_label(labels, accuracy)
```

**Arguments**

labels	a numerical vector of labels
accuracy	the accuracy of the label

**Value**

a vector of adjusted labels

**Examples**

```
format_label(c(0.87, 0.87, 0.9, 0.93, 0.95), 0.01)
format_label(c(0.87, 0.87, 0.9, 0.93, 0.95, 0.96, 0.96), 0.01)
```

---

`get_best`*Functions to get components from the data collecting object*

---

**Description**

Functions to get components from the data collecting object

**Usage**

```
get_best(dt, group = NULL)
get_start(dt, group = NULL)
get_interp(dt, group = NULL)
get_interp_last(dt, group = NULL)
get_anchor(dt, group = NULL)
get_search(dt)
get_dir_search(dt, ratio = 5, ...)
get_space_param(dt, ...)
get_theo(dt)
get_interrupt(dt, group = NULL, precision = 0.001)
get_search_count(dt, iter = NULL, group = NULL)
get_basis_matrix(dt)
```

**Arguments**

<code>dt</code>	a data object collected by the projection pursuit guided tour optimisation in the <code>tourr</code> package
<code>group</code>	the variable to label different runs of the optimiser(s)
<code>ratio</code>	numeric; a buffer value to deviate directional search points from the anchor points
<code>...</code>	other arguments passed to <code>compute_pca()</code>
<code>precision</code>	numeric; if the index value of the last interpolating point and the anchor point differ by <code>precision</code> , an interruption is registered
<code>iter</code>	the variable to be counted by

**Details**

`get_best`: extract the best basis found by the optimiser(s)  
`get_start`: extract the start point of the optimisation  
`get_interp`: extract the interpolation points  
`get_interp_last`: extract the last point in each interpolation  
`get_anchor`: extract the anchor points on the geodesic path  
`get_search`: extract search points in the optimisation (for `search_geodesic`)  
`get_dir_search`: extract directional search points (for `search_geodesic`)  
`get_space_param`: estimate the radius of the background circle based on the randomly generated points. The space of projected bases is a circle when reduced to 2D. A radius is estimated using the largest distance from the bases in the data object to the centre point.  
`get_theo`: extract the theoretical basis, if exist  
`get_interrupt`: extract the end point of the interpolation and the target point in the iteration when an interruption happens. The optimiser can find better basis on the interpolation path, an interruption is implemented to stop further interpolation from the highest point to the target point. This discrepancy is highlighted in the PCA plot.  
`get_search_count`: summarise the number of search points in each iteration  
`get_basis_matrix`: extract all the bases as a matrix

**Value**

a tibble object containing the best basis found by the optimiser(s)

**Examples**

```

get_search(holes_1d_geo)

get_anchor(holes_1d_geo)

get_start(holes_1d_better)

get_interrupt(holes_1d_better)

get_interp(holes_1d_better) %>% head()

get_basis_matrix(holes_1d_better) %>% head()

get_best(dplyr::bind_rows(holes_1d_better, holes_1d_geo), group = method)

get_search_count(holes_1d_better)
get_search_count(dplyr::bind_rows(holes_1d_better, holes_1d_geo), group = method)

get_interp_last(holes_1d_better)
get_interp_last(dplyr::bind_rows(holes_1d_better, holes_1d_geo), group = method)

res <- holes_1d_geo %>% compute_pca() %>% purrr::pluck("aug")
get_dir_search(res)

```

```
best <- matrix(c(0, 1, 0, 0, 0), nrow = 5)
holes_1d_better %>%
  bind_theoretical(best, tourr::holes(), raw_data = boa5) %>%
  get_theo()
```

---

holes\_1d\_geo

*Data objects collected during the projection pursuit optimisation*

---

## Description

Simulated data to demonstrate the usage of four diagnostic plots in the package, users can create their own guided tour data objects and diagnose with the visualisation designed in this package.

## Usage

```
holes_1d_geo
holes_1d_better
holes_1d_jellyfish
holes_2d_jellyfish
holes_2d_better
holes_2d_better_max_tries
```

## Format

An object of class `tbl_df` (inherits from `tbl`, `data.frame`) with 416 rows and 8 columns.  
An object of class `tbl_df` (inherits from `tbl`, `data.frame`) with 79 rows and 8 columns.  
An object of class `tbl_df` (inherits from `tbl`, `data.frame`) with 2500 rows and 8 columns.  
An object of class `tbl_df` (inherits from `tbl`, `data.frame`) with 2500 rows and 8 columns.  
An object of class `tbl_df` (inherits from `tbl`, `data.frame`) with 98 rows and 8 columns.  
An object of class `tbl_df` (inherits from `tbl`, `data.frame`) with 1499 rows and 8 columns.

## Details

The prefix `holes_*` indicates the use of holes index in the guided tour. The suffix `*_better/geo/jellyfish` indicates the optimiser used: `search_better`, `search_geodesic`, `search_jellyfish`.

## Examples

```
holes_1d_better %>%
  explore_trace_interp(interp_size = 2) +
  scale_color_continuous_botanical(palette = "fern")
```

---

plot_projection	<i>Plot the projection from the optimisation data collected from projection pursuit</i>
-----------------	---

---

### Description

Plot the projection from the optimisation data collected from projection pursuit

### Usage

```
plot_projection(  
  dt,  
  data,  
  id = NULL,  
  cols = NULL,  
  label = TRUE,  
  animate_along = NULL,  
  keep = 0.2  
)  
  
compute_projection(dt, data, id = NULL, cols = NULL)
```

### Arguments

dt	a data object collected by the projection pursuit guided tour optimisation in tourr
data	the original data
id	the grouping variable
cols	additional columns to include in the plot
label	logical, whether to label each panel by its index value
animate_along	the variable to animate along
keep	numeric, the proportion of the data to keep for animation (default is 0.2). Only used when 'animate_along' is not NULL

### Value

a ggplot object

### Examples

```
library(dplyr)  
holes_2d_jellyfish |>  
  filter(loop == 1, tries %in% seq(1, 50, 5)) |>  
  plot_projection(data = boa6)  
## Not run:  
library(dplyr)
```

```
# track the first jellyfish (loop == 1)
holes_2d_jellyfish |>
  filter(loop == 1) |>
  plot_projection(data = boa6, animate_along = tries, id = loop)

## End(Not run)
```

---

sample\_bases

*Function to calculate smoothness and squintability*

---

## Description

Function to calculate smoothness and squintability

## Usage

```
sample_bases(
  idx,
  data = sine1000,
  n_basis = 300,
  parallel = FALSE,
  best = matrix(c(0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 1), nrow = 6),
  min_proj_dist = NA,
  step_size = NA,
  seed = 123
)

## S3 method for class 'basis_df'
print(x, width = NULL, ...)

## S3 method for class 'basis_df'
tbl_sum(x)

calc_smoothness(
  basis_df,
  start_params = c(0.001, 0.5, 2, 2),
  other_gp_params = NULL,
  verbose = FALSE
)

## S3 method for class 'smoothness_res'
print(x, width = NULL, ...)

## S3 method for class 'smoothness_res'
tbl_sum(x)
```

```

calc_squintability(
  basis_df,
  method = c("ks", "nls"),
  scale = TRUE,
  bin_width = 0.005,
  other_params = NULL
)

## S3 method for class 'squintability_res'
print(x, width = NULL, ...)

## S3 method for class 'squintability_res'
tbl_sum(x)

fit_ks(basis_df, idx, other_params = NULL)

fit_nls(basis_df, other_params = NULL)

```

### Arguments

idx	character, the name of projection pursuit index function, e.g. "holes"
data	a matrix or data frame, the high dimensional data to be projected
n_basis	numeric, the number of random bases to generate
parallel	logic, whether to use parallel computing for calculating the index. Recommend for the stringy index.
best	a matrix, the theoretical/ empirical best projection matrix to calculate the projection distance from the simulated random bases.
min_proj_dist	only for squintability, the threshold for projection distance for the random basis to be considered in sampling
step_size	numeric, step size for interpolating from each random basis to the best basis, recommend 0.005
seed	numeric, seed for sampling random bases
x	objects with specialised printing methods
width	only used when <code>max.levels</code> is <code>NULL</code> , see above.
...	further arguments passed to or from other methods.
basis_df	the basis data frame returned from <code>sample_bases</code>
start_params	list, the starting parameters for the Gaussian process for smoothness
other_gp_params	list, additional parameters to be passed to <code>[GpGp::fit_model()]</code> for calculating smoothness
verbose	logical, whether to print optimisation progression when fitting the Gaussian process
method	either "ks" (kernel smoothing) or "nls" (non-linear least square) for calculating squintability.

scale	logic, whether to scale the index value to 0-1 in squintability
bin_width	numeric, the bin width to average the index value before fitting the kernel, recommend to set as the same as 'step' parameter
other_params	list additional parameters for fitting kernel smoothing or non-linear least square, see [stats::ksmooth()] and [stats::nls()] for details

### Examples

```
## Not run:
library(GpGp)
library(fields)
library(tourr)
basis_smoothness <- sample_bases(idx = "holes")
calc_smoothness(basis_smoothness)
basis_squint <- sample_bases(idx = "holes", n_basis = 100, step_size = 0.01, min_proj_dist = 1.5)
calc_squintability(basis_squint, method = "ks", bin_width = 0.01)

## End(Not run)
```

---

scale\_color\_continuous\_botanical  
*continuous scale colour function*

---

### Description

continuous scale colour function  
 Discrete scale colour function  
 continuous scale fill function  
 discrete scale fill function

### Usage

```
scale_color_continuous_botanical(palette = "fern", reverse = FALSE, ...)
scale_color_discrete_botanical(palette = "fern", reverse = FALSE, ...)
scale_fill_continuous_botanical(palette = "fern", reverse = FALSE, ...)
scale_fill_discrete_botanical(palette = "fern", reverse = FALSE, ...)
```

### Arguments

palette	colour palette from the botanical_palette
reverse	logical; if the colour should be reversed
...	other arguments passed into scale_color_gradientn

**Value**

a wrapper for continuous scales in the botanical palette

a wrapper for discrete scales in the botanical palette

a wrapper for continuous fill in the botanical palette

a wrapper for discrete fill in the botanical palette

---

sine1000

*Simulated sine, pipe, and gaussian mixture*

---

**Description**

Simulated sine and pipe data for calculating optimisation features. Each dataset has 1000 observations and the last two columns contain the intended structure with the rest being noise. The most commonly used ones are 'sine1000' and 'pipe1000', others have dimension suffixed.

**Usage**

sine1000

sine1000\_4d

sine1000\_6d

sine1000\_8d

pipe1000

pipe1000\_4d

pipe1000\_6d

pipe1000\_8d

pipe1000\_10d

pipe1000\_12d

boa

boa5

boa6

**Format**

An object of class `matrix` (inherits from `array`) with 1000 rows and 6 columns.

An object of class `matrix` (inherits from `array`) with 1000 rows and 4 columns.

An object of class `matrix` (inherits from `array`) with 1000 rows and 6 columns.

An object of class `matrix` (inherits from `array`) with 1000 rows and 8 columns.

An object of class `matrix` (inherits from `array`) with 1000 rows and 6 columns.

An object of class `matrix` (inherits from `array`) with 1000 rows and 4 columns.

An object of class `matrix` (inherits from `array`) with 1000 rows and 6 columns.

An object of class `matrix` (inherits from `array`) with 1000 rows and 8 columns.

An object of class `matrix` (inherits from `array`) with 1000 rows and 10 columns.

An object of class `matrix` (inherits from `array`) with 1000 rows and 12 columns.

An object of class `tbl_df` (inherits from `tbl`, `data.frame`) with 1000 rows and 10 columns.

An object of class `tbl_df` (inherits from `tbl`, `data.frame`) with 1000 rows and 5 columns.

An object of class `tbl_df` (inherits from `tbl`, `data.frame`) with 1000 rows and 6 columns.

**Examples**

```
library(ggplot2)
library(tidyr)
library(dplyr)
boa %>%
  pivot_longer(cols = x1:x10, names_to = "var", values_to = "value") %>%
  mutate(var = forcats::fct_relevel(as.factor(var), paste0("x", 1:10))) %>%
  ggplot(aes(x = value)) +
  geom_density() +
  facet_wrap(vars(var))

sine1000 |> ggplot(aes(x = V5, y = V6)) + geom_point() + theme(aspect.ratio = 1)
pipe1000_8d |> ggplot(aes(x = V5, y = V6)) + geom_point() + theme(aspect.ratio = 1)
pipe1000_8d |> ggplot(aes(x = V7, y = V8)) + geom_point() + theme(aspect.ratio = 1)
```

**Description**

The Huber plot presents the projection pursuit index values of 2D data in each 1D projection in polar coordinates, corresponding to each projection direction. It offers a simpler illustration of more complex projection from high-dimensional data to lower dimensions in projection pursuit. The function `prep_huber()` calculates each component required for the Huber plot (see details), which can then be supplied to various geom layers in `ggplot2`.

**Usage**

StatHuber

```
stat_huber(  
  mapping = NULL,  
  data = NULL,  
  geom = "path",  
  position = "identity",  
  ...,  
  index.fun,  
  na.rm = FALSE,  
  show.legend = NA,  
  inherit.aes = TRUE  
)
```

```
geom_huber(  
  mapping = NULL,  
  data = NULL,  
  stat = "identity",  
  position = "identity",  
  index.fun,  
  ref.circle.color = NULL,  
  ref.circle.colour = NULL,  
  ref.circle.linetype = "dashed",  
  ref.circle.linewidth = NULL,  
  idx.max.color = NULL,  
  idx.max.colour = NULL,  
  idx.max.linetype = "dashed",  
  idx.max.linewidth = NULL,  
  idx.profile.color = NULL,  
  idx.profile.colour = NULL,  
  idx.profile.linetype = "solid",  
  idx.profile.linewidth = NULL,  
  proj.points.color = NULL,  
  proj.points.colour = NULL,  
  proj.points.stroke = NULL,  
  proj.points.alpha = NULL,  
  proj.points.size = NULL,  
  proj.points.shape = NULL,  
  na.rm = FALSE,  
  show.legend = NA,  
  inherit.aes = TRUE,  
  ...  
)
```

GeomHuber

```
prep_huber_best_proj(data, index_fun)
```

```
theme_huber(...)
```

### Arguments

mapping	Set of aesthetic mappings created by <a href="#">aes()</a> . If specified and <code>inherit.aes = TRUE</code> (the default), it is combined with the default mapping at the top level of the plot. You must supply mapping if there is no plot mapping.
data	<p>The data to be displayed in this layer. There are three options:</p> <p>If <code>NULL</code>, the default, the data is inherited from the plot data as specified in the call to <a href="#">ggplot()</a>.</p> <p>A <code>data.frame</code>, or other object, will override the plot data. All objects will be fortified to produce a data frame. See <a href="#">fortify()</a> for which variables will be created.</p> <p>A function will be called with a single argument, the plot data. The return value must be a <code>data.frame</code>, and will be used as the layer data. A function can be created from a formula (e.g. <code>~ head(.x, 10)</code>).</p>
geom	<p>The geometric object to use to display the data for this layer. When using a <code>stat_*()</code> function to construct a layer, the <code>geom</code> argument can be used to override the default coupling between stats and geoms. The <code>geom</code> argument accepts the following:</p> <ul style="list-style-type: none"> <li>• A Geom <code>ggproto</code> subclass, for example <code>GeomPoint</code>.</li> <li>• A string naming the geom. To give the geom as a string, strip the function name of the <code>geom_</code> prefix. For example, to use <code>geom_point()</code>, give the geom as "point".</li> <li>• For more information and other ways to specify the geom, see the <a href="#">layer geom</a> documentation.</li> </ul>
position	<p>A position adjustment to use on the data for this layer. This can be used in various ways, including to prevent overplotting and improving the display. The <code>position</code> argument accepts the following:</p> <ul style="list-style-type: none"> <li>• The result of calling a position function, such as <code>position_jitter()</code>. This method allows for passing extra arguments to the position.</li> <li>• A string naming the position adjustment. To give the position as a string, strip the function name of the <code>position_</code> prefix. For example, to use <code>position_jitter()</code>, give the position as "jitter".</li> <li>• For more information and other ways to specify the position, see the <a href="#">layer position</a> documentation.</li> </ul>
...	<p>Other arguments passed on to <a href="#">layer()</a>'s <code>params</code> argument. These arguments broadly fall into one of 4 categories below. Notably, further arguments to the <code>position</code> argument, or aesthetics that are required can <i>not</i> be passed through ... Unknown arguments that are not part of the 4 categories below are ignored.</p> <ul style="list-style-type: none"> <li>• Static aesthetics that are not mapped to a scale, but are at a fixed value and apply to the layer as a whole. For example, <code>colour = "red"</code> or <code>linewidth = 3</code>. The geom's documentation has an <b>Aesthetics</b> section that lists the available options. The 'required' aesthetics cannot be passed on to the <code>params</code>. Please note that while passing unmapped aesthetics as vectors is</li> </ul>

technically possible, the order and required length is not guaranteed to be parallel to the input data.

- When constructing a layer using a `stat_*()` function, the `...` argument can be used to pass on parameters to the `geom` part of the layer. An example of this is `stat_density(geom = "area", outline.type = "both")`. The `geom`'s documentation lists which parameters it can accept.
- Inversely, when constructing a layer using a `geom_*()` function, the `...` argument can be used to pass on parameters to the `stat` part of the layer. An example of this is `geom_area(stat = "density", adjust = 0.5)`. The `stat`'s documentation lists which parameters it can accept.
- The `key_glyph` argument of `layer()` may also be passed on through `...`. This can be one of the functions described as [key glyphs](#), to change the display of the layer in the legend.

<code>index.fun, index_fun</code>	the projection pursuit index function, see examples
<code>na.rm</code>	If FALSE, the default, missing values are removed with a warning. If TRUE, missing values are silently removed.
<code>show.legend</code>	logical. Should this layer be included in the legends? NA, the default, includes if any aesthetics are mapped. FALSE never includes, and TRUE always includes. It can also be a named logical vector to finely select the aesthetics to display. To include legend keys for all levels, even when no data exists, use TRUE. If NA, all levels are shown in legend, but unobserved levels are omitted.
<code>inherit.aes</code>	If FALSE, overrides the default aesthetics, rather than combining with them. This is most useful for helper functions that define both data and aesthetics and shouldn't inherit behaviour from the default plot specification, e.g. <code>annotation_borders()</code> .
<code>stat</code>	The statistical transformation to use on the data for this layer. When using a <code>geom_*()</code> function to construct a layer, the <code>stat</code> argument can be used to override the default coupling between geoms and stats. The <code>stat</code> argument accepts the following: <ul style="list-style-type: none"> <li>• A Stat ggproto subclass, for example <code>StatCount</code>.</li> <li>• A string naming the stat. To give the stat as a string, strip the function name of the <code>stat_</code> prefix. For example, to use <code>stat_count()</code>, give the stat as "count".</li> <li>• For more information and other ways to specify the stat, see the <a href="#">layer stat</a> documentation.</li> </ul>
<code>ref.circle.color, ref.circle.linewidth</code>	<code>ref.circle.colour, ref.circle.linetype,</code> Default aesthetics for the reference circle
<code>idx.max.color, idx.max.linewidth</code>	<code>idx.max.colour, idx.max.linetype, idx.max.linewidth</code> Default aesthetics for the line indicating the best projection direction
<code>idx.profile.color, idx.profile.linewidth</code>	<code>idx.profile.colour, idx.profile.linetype,</code> Default aesthetics for the index profile line
<code>proj.points.alpha, proj.points.size, proj.points.shape</code>	<code>proj.points.color, proj.points.colour, proj.points.stroke,</code> Default aesthetics for the projected data points

**Format**

An object of class StatHuber (inherits from Stat, ggproto, gg) of length 3.

An object of class GeomHuber (inherits from Geom, ggproto, gg) of length 4.

**Details**

the `prep_huber()` function calculates components required for making the Huber plots. It returns a list including three elements:

**the `idx_df` data frame:** the x/y coordinates of the index value, in polar coordinates. Used for plotting the index value at each projection direction, with the reference circle.

**the `proj_df` data frame:** the best 1D projection. Used for plotting the 1D projection in histogram.

**the `slope` value:** the slope to plot in the Huber plot to indicate the direction of the best 1D projection.

**Examples**

```
library(ggplot2)
library(tourr)
library(ash)
data(randu)
# simplify the randu data into 2D for illustration
randu_std <- as.data.frame(apply(randu, 2, function(x) (x-mean(x))/sd(x)))
randu_std$yz <- sqrt(35)/6*randu_std$y-randu_std$z/6
randu_df <- randu_std[c(1,4)]

# main example: Huber plot with geom_huber()
randu_df |>
  ggplot() +
  geom_huber(aes(x = x, y = yz), index.fun = norm_bin(nr = nrow(randu_df))) +
  coord_fixed() +
  theme_huber()

# compute the best projection data for histogram
randu_huber_best <- prep_huber_best_proj(
  randu_df, index_fun = norm_bin(nr = nrow(randu_df))
)
randu_huber_best |>
  ggplot() +
  geom_histogram(aes(x = x), breaks = seq(-2.2, 2.4, 0.12)) +
  xlab("") + ylab("") +
  theme_bw() +
  theme(axis.text.y = element_blank())
```

---

theme_fern	<i>A specific theme for trace plots</i>
------------	---

---

**Description**

A specific theme for trace plots

**Usage**

theme\_fern()

**Value**

a ggplot2 theme for explore\_trace\_interp()

# Index

- \* **bind**
  - bind\_random, 12
  - bind\_random\_matrix, 12
  - bind\_theoretical, 13
- \* **datasets**
  - botanical\_palettes, 14
  - holes\_1d\_geo, 24
  - sine1000, 29
  - StatHuber, 30
- \* **draw functions**
  - add\_anchor, 3
  - add\_anno, 3
  - add\_dir\_search, 4
  - add\_end, 5
  - add\_interp, 5
  - add\_interp\_last, 6
  - add\_interrupt, 7
  - add\_search, 8
  - add\_space, 9
  - add\_start, 10
  - add\_theo, 11
- \* **main plot functions**
  - explore\_space\_start, 15
  - explore\_space\_tour, 17
  - explore\_trace\_interp, 18
  - explore\_trace\_search, 19
- add\_anchor, 3, 4–11
- add\_anno, 3, 3, 4–11
- add\_dir\_search, 3, 4, 4, 5–11
- add\_end, 3, 4, 5, 6–11
- add\_interp, 3–5, 5, 7–11
- add\_interp\_last, 3–6, 6, 8–11
- add\_interrupt, 3–7, 7, 8–11
- add\_search, 3–8, 8, 9–11
- add\_space, 3–8, 9, 10, 11
- add\_start, 3–9, 10, 11
- add\_theo, 3–10, 11
- aes(), 32
- annotation\_borders(), 33
- bind\_random, 12, 13, 14
- bind\_random\_matrix, 12, 12, 14
- bind\_theoretical, 12, 13, 13
- boa (sine1000), 29
- boa5 (sine1000), 29
- boa6 (sine1000), 29
- botanical\_pal (botanical\_palettes), 14
- botanical\_palettes, 14
- calc\_smoothness (sample\_bases), 26
- calc\_squintability (sample\_bases), 26
- clean\_method, 15
- compute\_pca (flip\_sign), 20
- compute\_projection (plot\_projection), 25
- explore\_space\_end
  - (explore\_space\_start), 15
- explore\_space\_pca
  - (explore\_space\_start), 15
- explore\_space\_start, 15, 18–20
- explore\_space\_tour, 16, 17, 19, 20
- explore\_trace\_interp, 16, 18, 18, 20
- explore\_trace\_search, 16, 18, 19, 19
- fit\_ks (sample\_bases), 26
- fit\_nls (sample\_bases), 26
- flip\_sign, 20
- format\_label, 21
- fortify(), 32
- geom\_huber (StatHuber), 30
- GeomHuber (StatHuber), 30
- get\_anchor (get\_best), 22
- get\_basis\_matrix (get\_best), 22
- get\_best, 22
- get\_dir\_search (get\_best), 22
- get\_interp (get\_best), 22
- get\_interp\_last (get\_best), 22
- get\_interrupt (get\_best), 22
- get\_search (get\_best), 22

get\_search\_count (get\_best), 22  
get\_space\_param (get\_best), 22  
get\_start (get\_best), 22  
get\_theo (get\_best), 22  
ggplot(), 32

holes\_1d\_better (holes\_1d\_geo), 24  
holes\_1d\_geo, 24  
holes\_1d\_jellyfish (holes\_1d\_geo), 24  
holes\_2d\_better (holes\_1d\_geo), 24  
holes\_2d\_better\_max\_tries  
    (holes\_1d\_geo), 24  
holes\_2d\_jellyfish (holes\_1d\_geo), 24

key glyphs, 33

layer geom, 32  
layer position, 32  
layer stat, 33  
layer(), 32, 33

pipe1000 (sine1000), 29  
pipe1000\_10d (sine1000), 29  
pipe1000\_12d (sine1000), 29  
pipe1000\_4d (sine1000), 29  
pipe1000\_6d (sine1000), 29  
pipe1000\_8d (sine1000), 29  
plot\_projection, 25  
prep\_huber\_best\_proj (StatHuber), 30  
prep\_space\_tour (explore\_space\_tour), 17  
print.basis\_df (sample\_bases), 26  
print.smoothness\_res (sample\_bases), 26  
print.squintability\_res (sample\_bases),  
    26

sample\_bases, 26  
scale\_color\_continuous\_botanical, 28  
scale\_color\_discrete\_botanical  
    (scale\_color\_continuous\_botanical),  
    28  
scale\_fill\_continuous\_botanical  
    (scale\_color\_continuous\_botanical),  
    28  
scale\_fill\_discrete\_botanical  
    (scale\_color\_continuous\_botanical),  
    28

sine1000, 29  
sine1000\_4d (sine1000), 29  
sine1000\_6d (sine1000), 29  
sine1000\_8d (sine1000), 29  
stat\_huber (StatHuber), 30  
StatHuber, 30

tbl\_sum.basis\_df (sample\_bases), 26  
tbl\_sum.smoothness\_res (sample\_bases),  
    26  
tbl\_sum.squintability\_res  
    (sample\_bases), 26  
theme\_fern, 35  
theme\_huber (StatHuber), 30