# VISUALIZATION & SHINY

CEPE GENES
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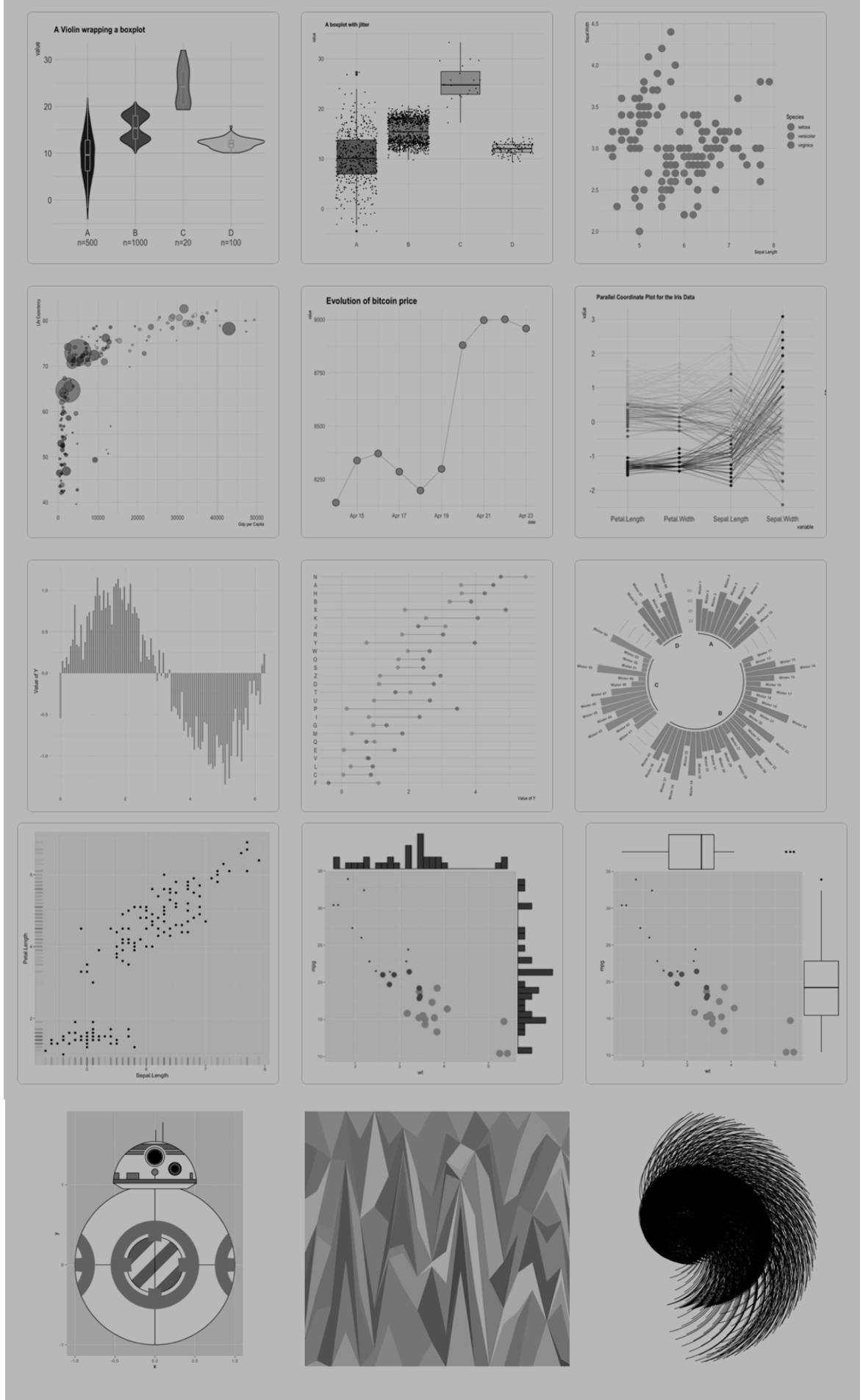
# Program

- Visualization : building graphs with ggplot2
  - Why ggplot2 ?
  - Grammar of Graphics : data, aesthetics, geometry, design, faceting
  - Going through different geometries [practice]
  - Improving design [practice]
  - Practice
- Building dashboard and web apps with Shiny
  - Starting off with an example, UI vs Server [practice]
  - Overall code development strategy
  - Inputs & outputs [practice]
  - Creating (re)actions [practice]
  - (Meta)data management [practice]
  - Tips & ressources

# VISUALIZATION

## BUILDING GRAPHS WITH

# Why ggplot2 ?

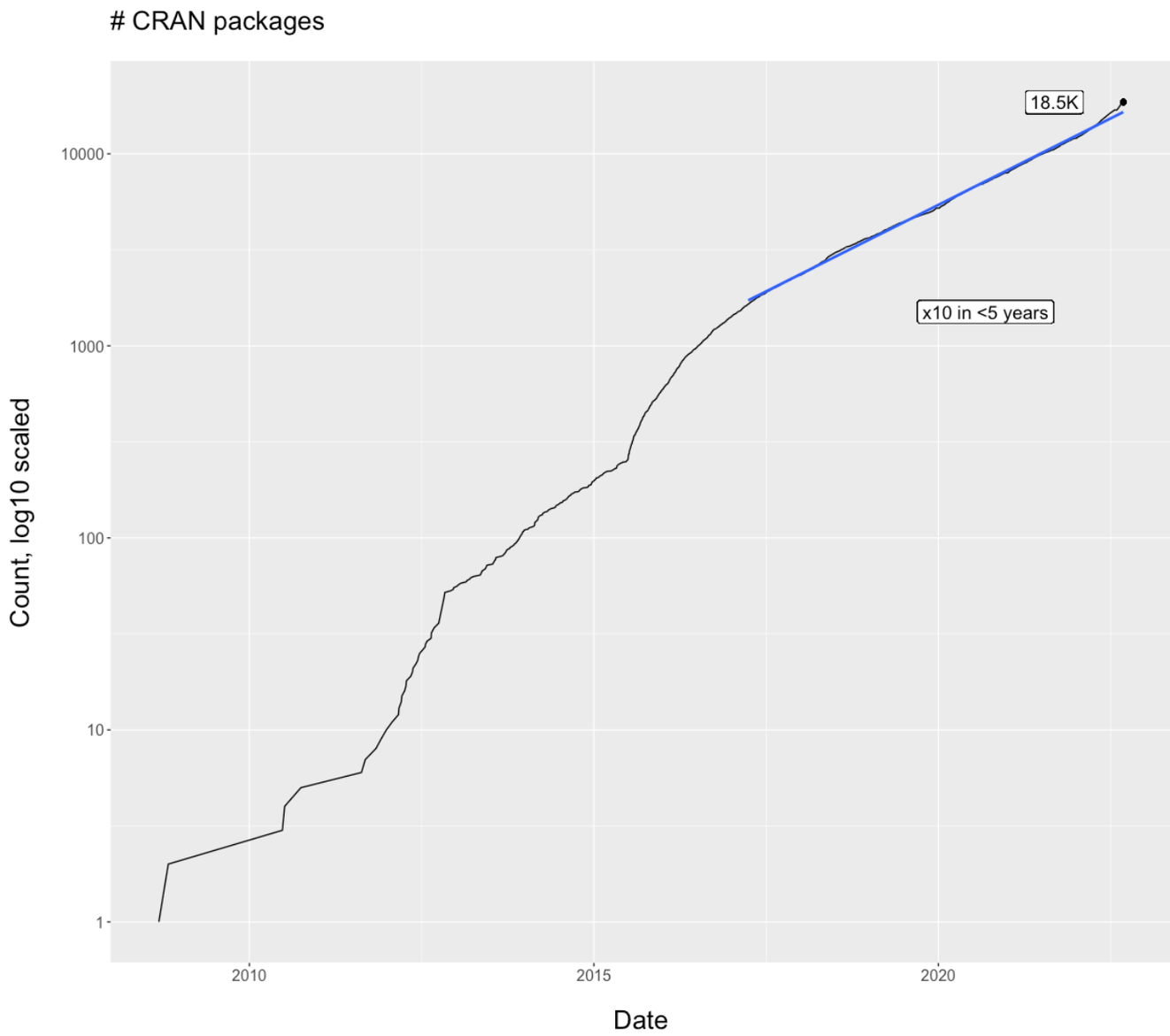
## R packages - what is out there ??

A lot of base methods to know

So many packages (see plot beside), it's so hard to keep up.

Search + stack overflow + R vignettes can help get some clues as to what to use.

Since ~10 years, a new standard package arose for anything data related : the tidyverse package


And that's not counting other package repositories and packages hosted on GitHub !

# Why ggplot2 ?

## R packages - the tidyverse

**tidyverse**

opinionated collection of R packages designed for data science

```
library(tidyverse)
```

- **ggplot2**: data visualization
- **dplyr**: data wrangling
- **tidyr**: data tidying
- **readr**: data reading/writing
- **forcats**: working with factors
- **stringr**: working with strings
- **tibble**: modern data frames
- **purrr**: functional programming

`install.packages(tidyverse)` above + a few more

# Why ggplot2 ?

## R packages - the dataviz landscape

## ggplot2

The Standard package for data visualization

3 300K Monthly Downloads

Extremely readable syntax (grammar of graphics)

Cost of entry : medium

Maintained by RStudio and co, part of the tidyverse

#1 choice of R community and the standard of graphics

can be re-used in Python via nineplot

so many packages are built as add-ons of ggplot2 :

## Base plots

Installed by default

Hard/customized plots : nightmare

Syntax quickly becomes unreadable

Not the nicest designs

## Lattice, DiagrammeR, igraph, ...

so many packages, often doing single-type plot

far less used than ggplot2 and extensions

most of what they do can be done via ggplot2 and extensions

often require less 'work' than ggplot2 for quick tests

| Package | Nb monthly downloads |
|---|---|
| Cowplot | 280K |
| Lattice | 155K |
| LatticeExtra | 240K |
| ggrepel* | 500K |

*ggplot2 add-on, adding nice annotation to graph

## Plotly, Echarts4, ...

Cross-platform

Very pretty outputs

Interactivity

Similar grammar to ggplot2

Much less support

300K Monthly Downloads

3K Monthly Downloads

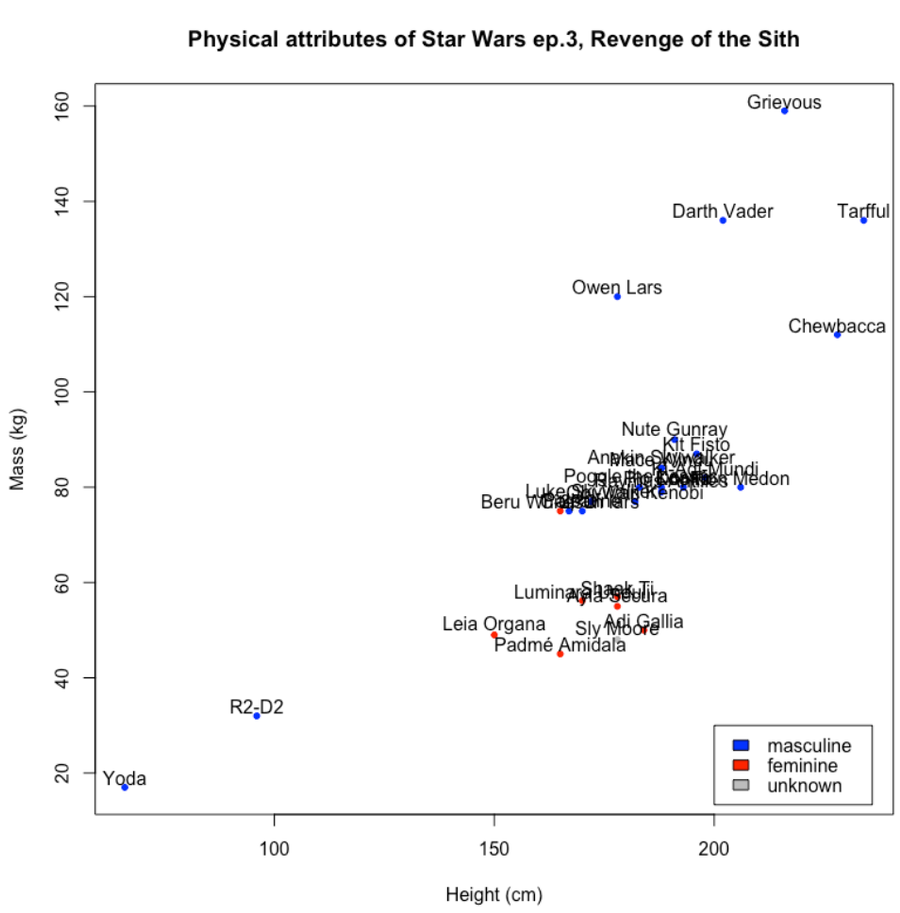
Check https://cran.r-project.org/web/views/Graphics.html

# Why ggplot2 ?

From base to ggplot2 - radical change of grammar, for the best

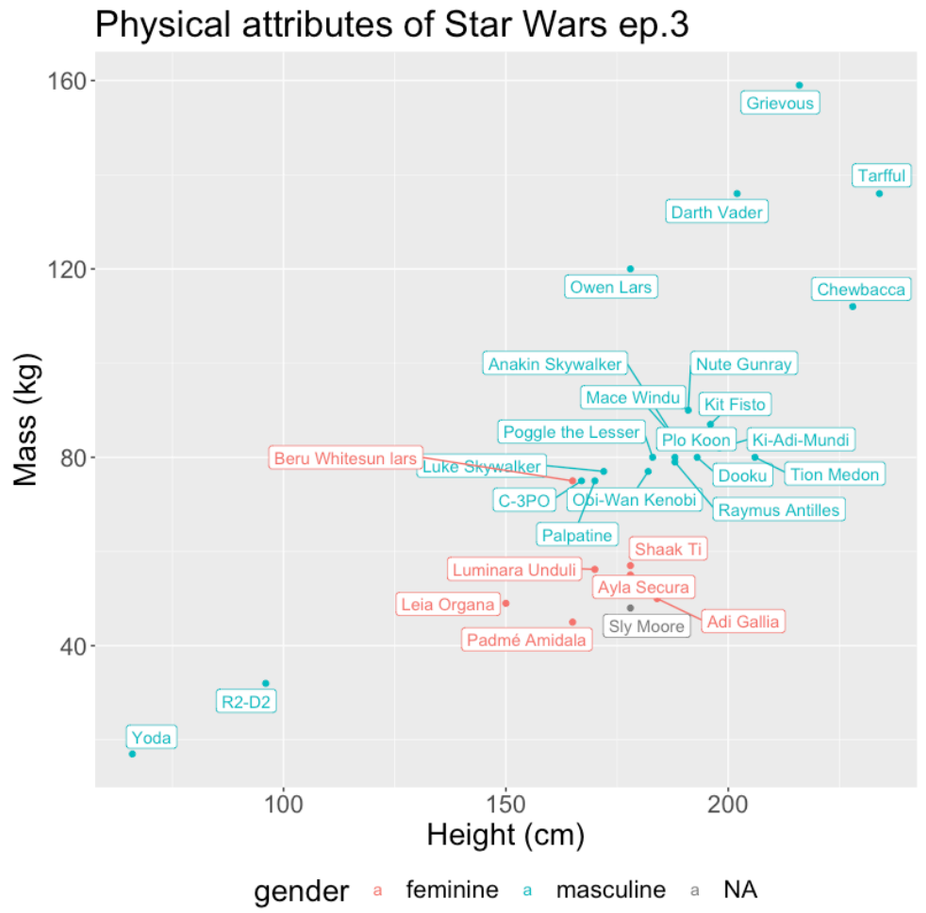
## base

```
l = c('masculine' = 'blue', 'feminine' = 'red')
plot(x = starwars_ep3$height, y = starwars_ep3$mass,
     col = map_var(l, starwars_ep3$gender, 'gray'), pch = 20,
     main = 'Physical attributes of Star Wars ep.3',
     xlab = 'Height (cm)', ylab = 'Mass (kg)')
text(x = starwars_ep3$height, y = starwars_ep3$mass + 2,
     labels = starwars_ep3$name)
legend(x = 200, y = 30, fill = c(as.character(l), 'gray'),
       legend = c(names(l), 'unknown'))
```




## ggplot2

```
ggplot(data = starwars_ep3) +
  aes(x = height, y = mass, label = name, col = gender) +
  geom_point() +
  geom_label_repel() +
  labs(title = 'Physical attributes of Star Wars ep.3',
       x = 'Height (cm)', y = 'Mass (kg)') +
  theme(text = element_text(size = 20), legend.position = 'bottom')
```



# How ggplot2 ?

Key elements of the Grammar of Graphics

INIT GGPLOT
Specifying a Tibble as data

AESTHETICS
What to put in x, y, color (contour), fill (filling color), shape, size

GEOMETRY
geom_point
geom_line
geom_hist
geom_boxplot
...

DESIGN
labs, theme

```
1   library(tidyverse)
2   library(ggrepel)
3
4   data("starwars")
5
6   starwars_ep3 = starwars %>%
7     filter(map_lgl(films, function(x) "Revenge of the Sith" %in% x))
8
9   ggplot(data = starwars_ep3) +
10    aes(x = height, y = mass, label = name, col = gender) +
11    geom_point() +
12    geom_label_repel() +
13    labs(title = 'Physical attributes of Star Wars ep.3',
14         x = 'Height (cm)', y = 'Mass (kg)') +
15    theme(text = element_text(size = 20), legend.position = 'bottom')
```

FACETTING
split graphic by categories

`+`
Operator to combine ggproto objects

LET's PRACTICE !

# How ggplot2 ?

Practice & Tips

## Some Ressources

stackoverflow

https://raw.githubusercontent.com/rstudio/cheatsheets/main/pngs/data-visualization.png

https://ggplot2.tidyverse.org

https://www.r-graph-gallery.com

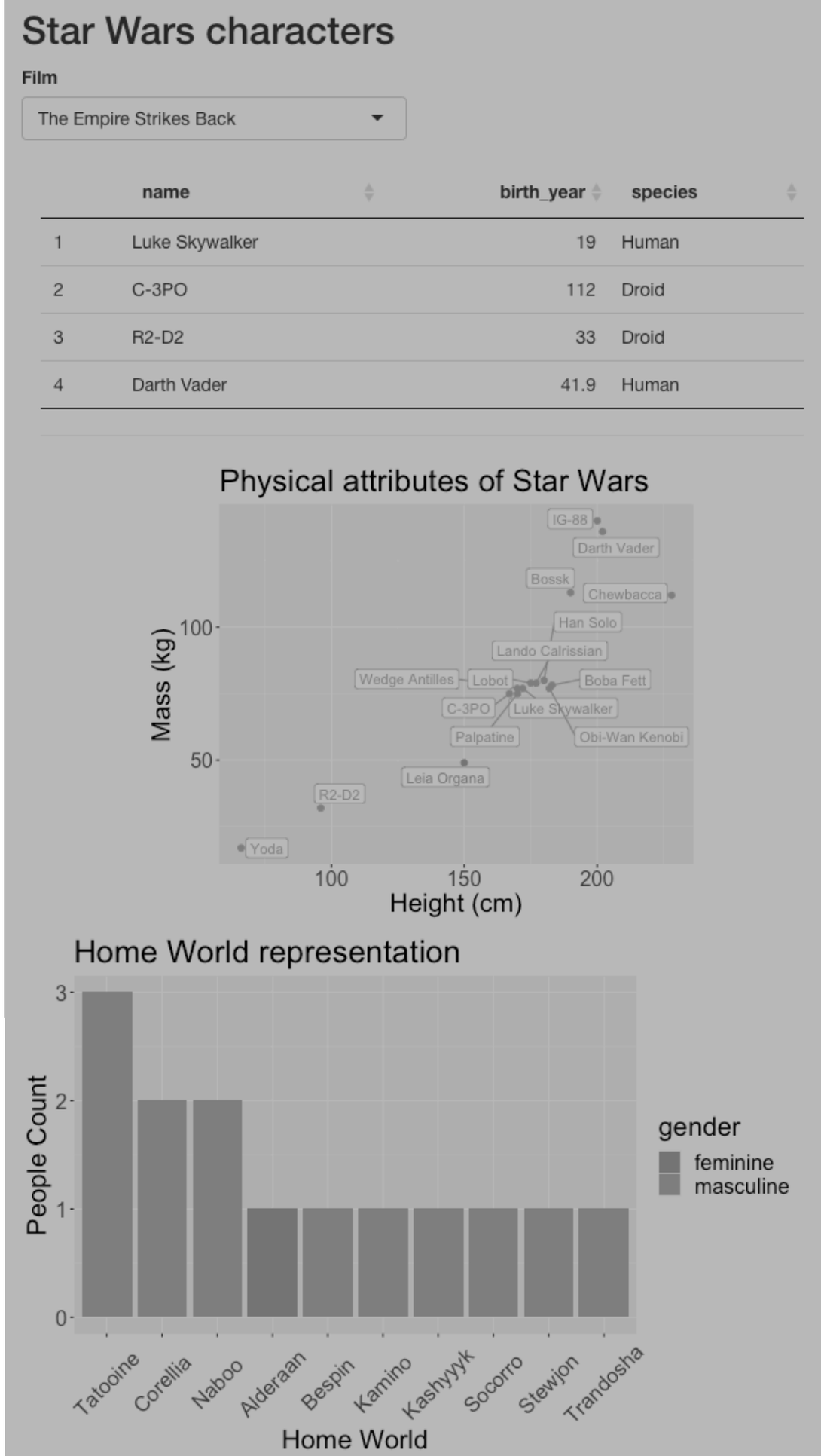
https://www.r-pkg.org/search.html?q=visualization

## Some tips & common issues

> add interactivity easily : transform ggplot to plotly graph
> check error message
> color/fill are often confused
> R interprets code without regard of line indexes, so make sure you don’t have open code before, and that all ‘+’ signs are present

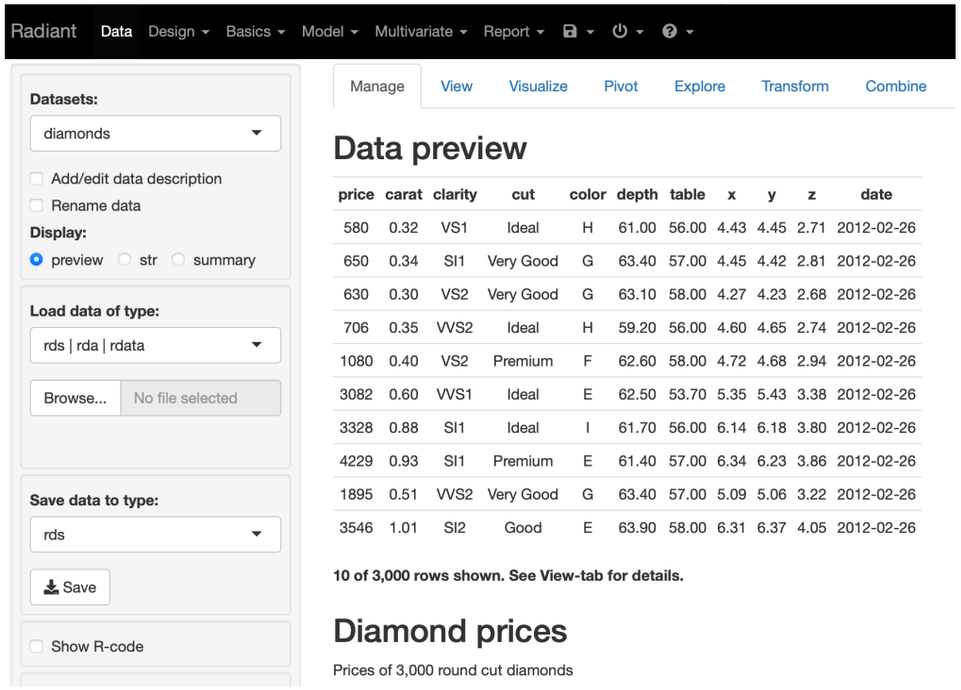
# DASHBOARDS & WEBAPPS

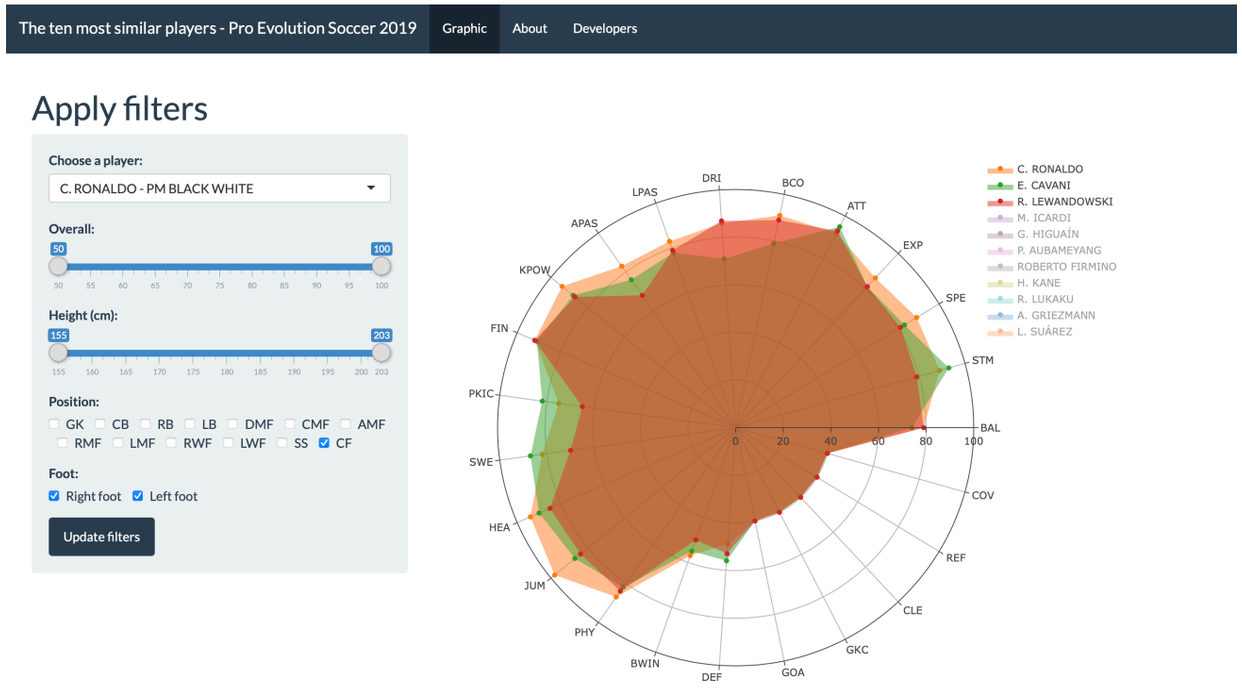
WITH

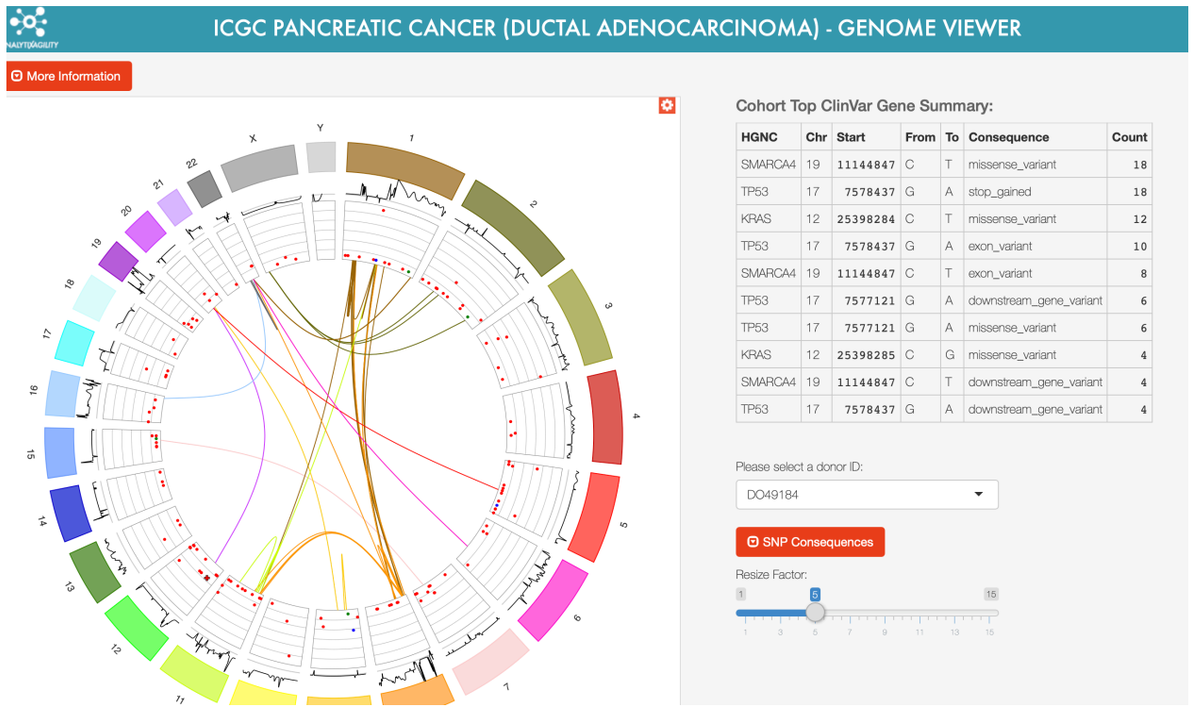



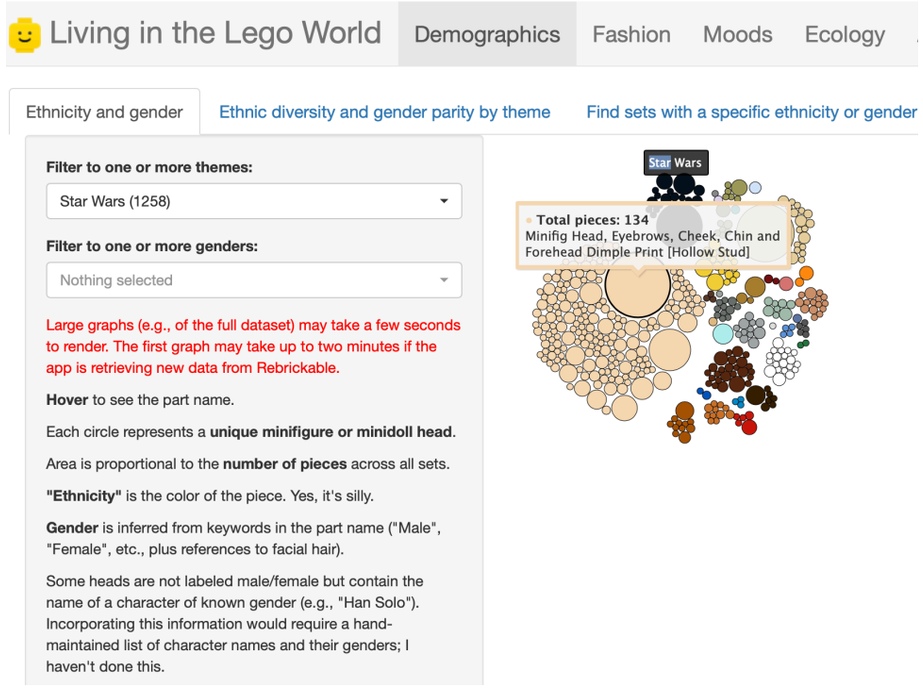
# Objective

Learn how to build such beautiful apps, with (mostly) R code.



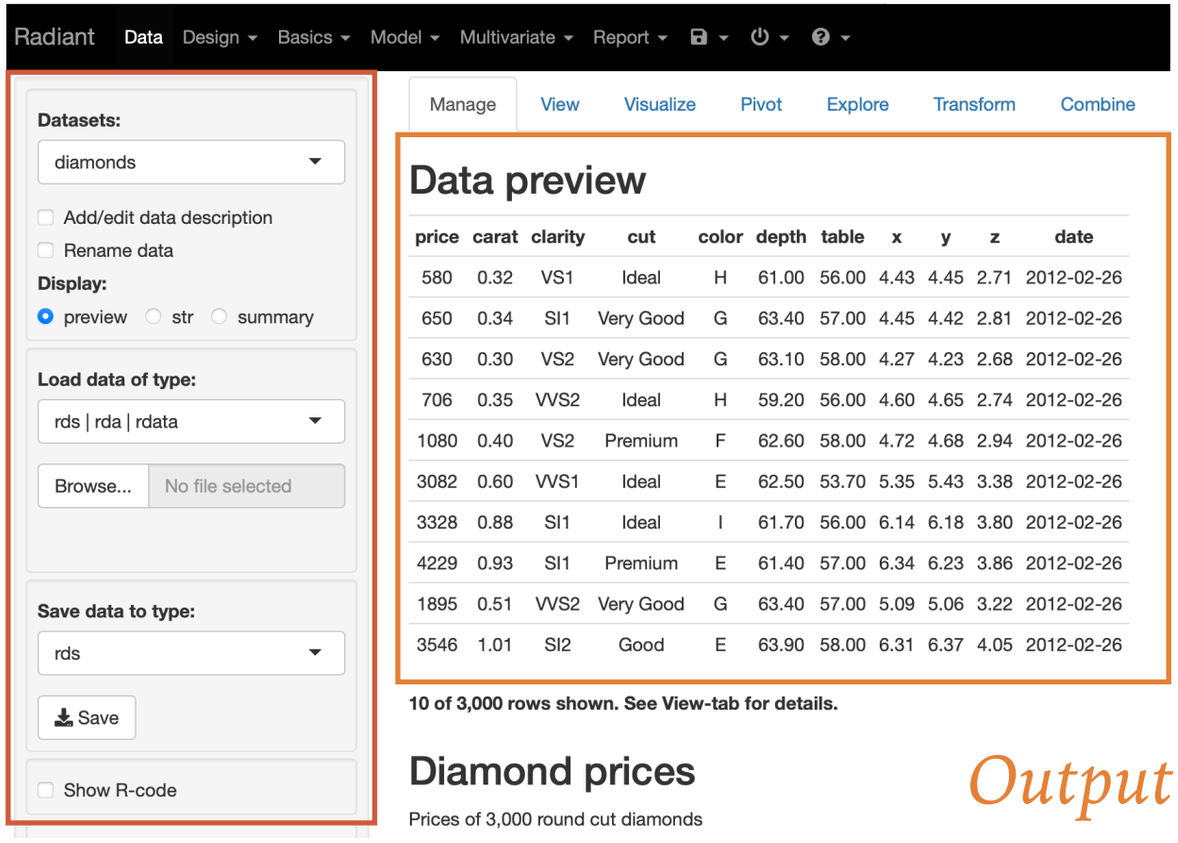



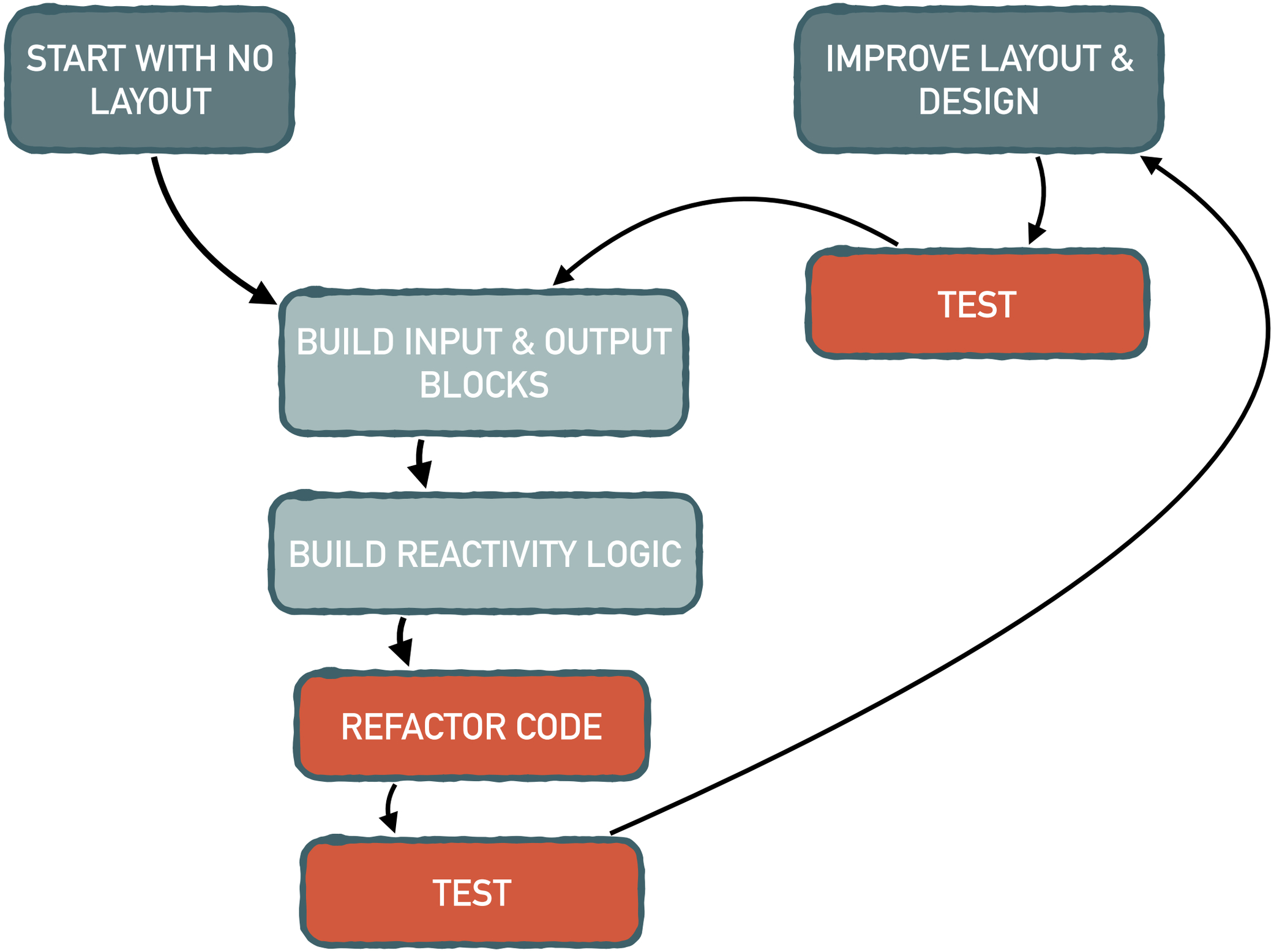
# Basic elements

An app can be decomposed in five essentials:

- Inputs : where the user can specify information
- Outputs : where information is displayed and visualized
- Reactivity links : defining how some element is affected by another (e.g. an output by an input)
- Layout : how inputs and outputs and other fixed material (e.g. logo) is displayed on the app
- Custom design : font and color choices for the app



# Simple process for building the app



# Geyser example

Follow these steps :

1. File > New File > Shiny Web App
2. A popup appears : put a random name (modifiable after), and click on `Single file`
3. A folder is created with an `app` R file. Open it. <!> install.packages('shiny')
4. Click on the RunApp button to see the result !

## User Interface

```r
# Define UI for application that draws a histogram
ui <- fluidPage(

    # Application title
    titlePanel("Old Faithful Geyser Data"),

    # Sidebar with a slider input for number of bins
    sidebarLayout(
        sidebarPanel(
            sliderInput("bins",
                        "Number of bins:",
                        min = 1,
                        max = 50,
                        value = 30)
        ),

        # Show a plot of the generated distribution
        mainPanel(
           plotOutput("distPlot")
        )
    )
)
```

Check value of ui to see html code

## Server

```r
# Define server logic required to draw a histogram
server <- function(input, output) {

    output$distPlot <- renderPlot({
        # generate bins based on input$bins from ui.R
        x    <- faithful[, 2]
        bins <- seq(min(x), max(x), length.out = input$bins + 1)

        # draw the histogram with the specified number of bins
        hist(x, breaks = bins, col = 'darkgray', border = 'white')
    })
}

# Run the application
shinyApp(ui = ui, server = server)
```

LAYOUT | INPUT | OUTPUT

Three basic components with which you'll be working

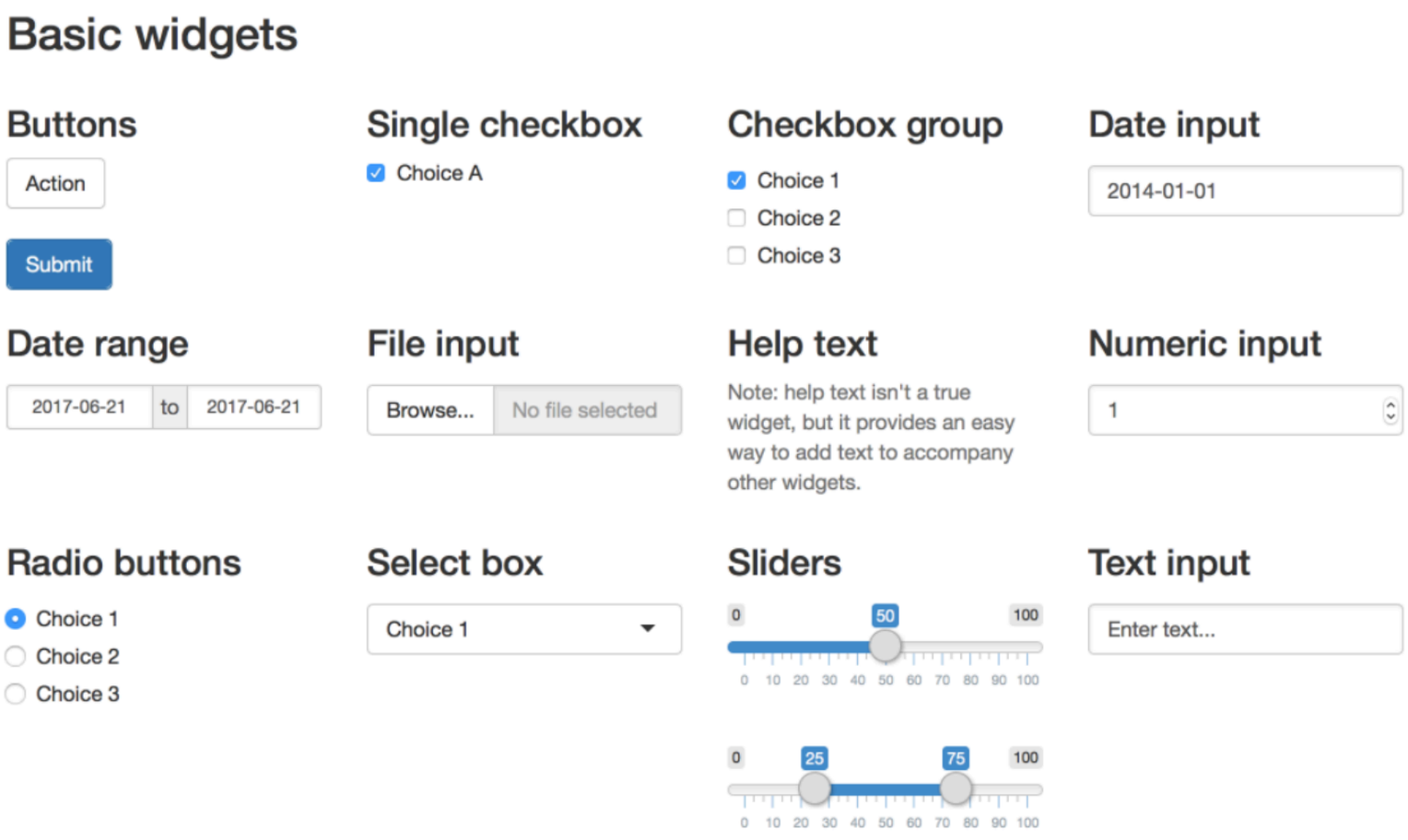
# Plan

- Playing with basic inputs and outputs
- Event reactivity
- Handling data properly
- Create your own Shiny App !

# Input widgets

Inputs are called in server function with input$some_input_id, as defined in the UI

| UI input |
|---|
| actionButton |
| checkboxGroupInput |
| checkboxInput |
| dateInput |
| dateRangeInput |
| fileInput |
| helpText |
| numericInput |
| radioButtons |
| selectInput |
| sliderInput |
| textInput |




Check out http://shinyapps.dreamrs.fr/shinyWidgets/ for advanced selection of widgets

# Handling outputs

Outputs are specified in UI (e.g. textOutput) and the rendering is specified in server (e.g. output$some_output_id <- renderOutput({ …}) )

| Creating : | In UI | In server |
|---|---|---|
| Raw HTML | `htmlOutput('id')`<br>`uiOutput('id')` | `output$id = renderUI({ …})` |
| Text | `textOutput('id')`<br>`verbatimTextOutput('id')` | `output$id = renderText({ …})`<br>`output$id = renderPrint({ …})` |
| Table | `tableOutput('id')` | `output$id = renderTable({ …})` |
| DataTable | `dataTableOutput('id')` | `output$id = renderDataTable({ …})` |
| Image | `imageOutput('id')` | `output$id = renderImage({ …})` |
| Plot | `plotOutput('id')` | `output$id = renderPlot({…})` |
| Plotly | `plotlyOutput('id')` | `output$id = renderPlotly({ …})` |

Render your plots interactive, with hovering and clicking options
https://shiny.rstudio.com/articles/plot-interaction.html

# The need for refactoring

## Before

```
server = shinyServer(function(input, output) {

  df <- reactive({ starwars %>%  filter(map_lgl(films, function(x) input$film %in% x)) })

  output$table1 <- renderDataTable({
    datatable(head(df()[,c('name', 'birth_year', 'species')], 4),
              options = list(dom = 't'))
  })

  output$physic1 <- renderPlot({
    h = df()
    print(h)
    ggplot(data = h) +
      aes(x = height, y = mass, label = name, col = gender) +
      geom_point(cex = 2) +
      geom_label_repel() +
      coord_fixed() +
      labs(title = 'Physical attributes of Star Wars',
           x = 'Height (cm)', y = 'Mass (kg)') +
      theme(text = element_text(size = 20), legend.position = 'bottom')
  })

  output$physic2 <- renderPlot({
    hh = df() %>%
      filter(is.na(homeworld) == FALSE) %>%
      count(homeworld, gender) %>%
      group_by(homeworld) %>%
      mutate(nn = sum(n)) %>%
      slice_max(order_by = nn, n = 10)
    ggplot(data = hh) +
      aes(x = reorder(homeworld, -n), y = n, fill = gender) +
      geom_bar(stat = 'identity') +
      labs(x = 'Home World', y = 'People Count', title = 'Home World representation') +
      theme(text = element_text(size = 20),
            axis.text.x = element_text(vjust = 0.5, angle = 45))
  })

})
```

## After

```
height_vs_mass_graph <- function(filtered_df){...}

homeworld_count <- function(filtered_df){...}
```

```
server = shinyServer(function(input, output) {

  df <- reactive({ starwars %>%  filter(map_lgl(films, function(x) input$film %in% x)) })

  output$table1 <- renderDataTable({
    datatable(head(df()[,c('name', 'birth_year', 'species')], 4),
              options = list(dom = 't'))
  })

  output$physic1 <- renderPlot({ height_vs_mass_graph(df()) })

  output$physic2 <- renderPlot({ homeworld_count(df()) })

})
```

Graph code and data process can render overall code readability a nightmare
=> create outside app functions for increased readability + testing

The app can be organized in different ways :

- functions called can be in separate files, sourced at the beginning
- ui and server can be defined in separate files

You can even integrate it in markdown document !!

# Introducing reactivity

| | Reactivity functions | Objective | Output |
|---|---|---|---|
| Trigger | `observe` | Do some operations whenever a called input changes | None |
| | `observeEvent` | Do some operations whenever a trigger input is modified | None |
| | `isolate` | Isolate an input such that reactivity is not affected by change of its value | None |
| Data handling | `reactive` | Compute some data whenever a called input changes | Function |
| | `eventReactive` | Compute some data whenever a trigger input is modified | Function |
| | `reactiveValues` | Store data that you wish to be accessible and modifiable from any part of the server -> best way to handle loaded data on app | None |

**Check out https://rstudio.github.io/reactlog/ to test your reactivity processes**

# Reactivity - Trigger

observe({}) - do some operations whenever a called input changes, no output

```
ui <- fluidPage(
  textInput(inputId = "free_input", label = "Free Input"),
  selectInput(inputId = "film", label = "Film",
              choices = unique(unlist(starwars$films)))
)

random_code <- function(){
  paste0(sample(letters, 10), collapse = '')
}

server <- function(input, output, session) {

  observe({
    print(input$film)
    updateSliderInput(inputId = "free_input",
                      session = session,
                      value = random_code())
  })

}

shinyApp(ui, server)
```

LAYOUT | INPUT | OUTPUT | REACTIVITY

# Reactivity - Trigger

observeEvent({}) : do some operations whenever a specific input is modified, no output

```
3  ui <- fluidPage(
4    actionButton("doMagicTrick", "Show something"),
5    textOutput("myText")
6  )
7
8  server <- function(input, output) {
9    observeEvent(input$doMagicTrick, {
10     output$myText <- renderText({
11       paste0('You are ...', sample(starwars$name, 1), '!')
12     })
13   })
14 }
15
16 shinyApp(ui, server)
```

LAYOUT | INPUT | OUTPUT | REACTIVITY

# Reactivity - Trigger / or not

## isolate({}) - stop input modification from causing changes

```
ui <- fluidPage(
  textInput(inputId = "free_input", label = "Free Input"),
  selectInput(inputId = "film",label = "Film", choices = unique(unlist(starwars$films))),
  textOutput('output_text')
)

server <- function(input, output) {

  output$output_text <- renderText({
    paste0(isolate(input$film), " - ", input$free_input)
  })

}

shinyApp(ui, server)
```

LAYOUT INPUT OUTPUT REACTIVITY

# Reactivity - Data handling

## reactive({}) - update dataset required for several outputs when input changes

```
5  ui <- fluidPage(
6    selectInput(inputId = "film",label = "Film", choices = unique(unlist(starwars$films))),
7    textOutput('genericInfo'),
8    br(),
9    h5('First 4 characters : '),
10   dataTableOutput("myTable")
11 )
12
13 server <- function(input, output, session) {
14
15   df <- reactive({
16     starwars %>%
17       filter(map_lgl(films, function(x) input$film %in% x))
18   })
19
20   output$genericInfo <- renderText({
21     paste0('Nb of characters : ', nrow(df()))
22   })
23
24   output$myTable <- renderDataTable({
25     datatable(head(df()[,c('name', 'birth_year', 'species')], 4),
26               options = list(dom = 't'))
27   })
28
29
30 }
31
32 shinyApp(ui, server)
```

Note that reactive outputs a function callable anywhere in server

LAYOUT INPUT OUTPUT REACTIVITY

# Reactivity - Data handling

## eventReactive({}) : when a single input is modified, output new data

```
ui <- fluidPage(
  headerPanel("Example eventReactive"),

  mainPanel(

    # input field
    textInput("user_text", label = "Enter some text:", placeholder = "Please enter some text."),

    # submit button
    actionButton("submit", label = "Submit"),

    # display text output
    textOutput("text"))
)

server <- function(input, output) {

  # reactive expression
  text_reactive <- eventReactive(input$submit, {
    input$user_text
  })

  # text output
  output$text <- renderText({
    text_reactive()
  })
}
```

Note that eventReactive outputs a function callable anywhere in server

LAYOUT INPUT OUTPUT REACTIVITY

# Reactivity - Data handling

## reactiveValues({}) : handling data

```
ui <- fluidPage(
    # input field
    textInput("user_text", label = "Enter some text:", placeholder = "Please enter some text."),
    actionButton("submit", label = "Submit"),

    # display text output
    textOutput("text")
)

server <- function(input, output) {

  # observe event for updating the reactiveValues
  observeEvent(input$submit,
               {
                 text_reactive$text <- input$user_text
               })

  # reactiveValues
  text_reactive <- reactiveValues(
    text = "No text has been submitted yet."
  )

  # text output
  output$text <- renderText({
    text_reactive$text
  })
}
```

Note that reactiveValues outputs a list callable anywhere in server

# Grid Layout

```
ui <- fluidPage(

  title = "Diamonds Explorer",

  plotOutput('plot'),

  hr(),

  fluidRow(
    column(3,
      h4("Diamonds Explorer"),
      sliderInput('sampleSize', 'Sample Size',
                  min=1, max=nrow(dataset), value=min(1000, nrow(dataset)),
                  step=500, round=0),
      br(),
      checkboxInput('jitter', 'Jitter'),
      checkboxInput('smooth', 'Smooth')
    ),
    column(4, offset = 1,
      selectInput('x', 'X', names(dataset)),
      selectInput('y', 'Y', names(dataset), names(dataset)[[2]]),
      selectInput('color', 'Color', c('None', names(dataset)))
    ),
    column(4,
      selectInput('facet_row', 'Facet Row', c(None='.', names(dataset))),
      selectInput('facet_col', 'Facet Column', c(None='.', names(dataset)))
    )
  )
)
```

# Layout & design

## Improving layout

For custom layout
https://shiny.rstudio.com/articles/layout-guide.html

Rely on shiny extensions
https://rstudio.github.io/flexdashboard/articles/examples.html [flexdashboard]
https://rstudio.github.io/shinydashboard/examples.html [shinydashboard]
https://rinterface.github.io/shinydashboardPlus/index.html [shinydashboardPlus]

## Improve rendering

Customize theme
https://shiny.rstudio.com/articles/themes.html

Customizing UI with html and css

## Deployment

Where ? Local/Cloud servers with R env running, shinyapp.io

Authentication process : shinymanager, Shinyauthr, https://shiny.rstudio.com/gallery/authentication-and-database.html

# Deployment

## Where to deploy the app, and how ?

Local machine with R env running

Server with R env running - access and setup requires IT expertise if internal, if external quite easy to do (see this auto on using AWS's servers to deploy an app https://www.charlesbordet.com/en/guide-shiny-aws/#)

For open access : shinyapp.io

## Authentication management in the app

Packages: shinymanager, Shinyauthr

Studio resource: https://shiny.rstudio.com/gallery/authentication-and-database.html

## Response time

R profiling is a great tool to look at the amount of time each piece of your code takes, in order to prioritize dev efforts

# Recommended reading