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# PH 718 Data Management and Visualization in R

## Part 6: Interactive Plotting

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2025/04/24 17:11:06

### Examples of interactive plotting

**Example 1: Interactive 3D plot of surface  $z=x^2 + y^2$  (also in Part 4: Introduction to tidyverse)**

```
x <- seq(-pi, pi, length = 50)
y <- x
z_matrix <- outer(x, y, function(x, y) x^2 + y^2)

plotly::plot_ly(
  x = ~x, y = ~y, z = ~z_matrix,
  type = "surface",
  colorscale = "Viridis"
) |> plotly::layout(
  title = "3D Surface Plot:  $f(x, y) = x^2 + y^2$ ",
  scene = list(
    xaxis = list(title = "X-axis"),
    yaxis = list(title = "Y-axis"),
    zaxis = list(title = "Z-axis")
  )
)
```

**Example 2: Interactive scatter plot deployed online**

<https://shiny.posit.co/>

**Example 3: Interactive maps developed by the US Census Bureau**

<https://www.census.gov/programs-surveys/geography/data/interactive-maps.html>

### Why interactive plotting is beneficial

- Enhances user engagement by allowing direct interaction with visualizations.
- Improves exploration of complex data through dynamic filtering, zooming, and detailed tooltips, uncovering patterns and insights not immediately apparent from static plots.
- Facilitates the presentation of plots without code adjustments.

## plotly::ggplotly: converting ggplot2 figures to interactive ones

### Interactive scatter plot

```
library(tidyverse)
p <- ggplot(mtcars, aes(x = wt, y = mpg, color = factor(cyl))) +
  geom_point(size = 3) +
  labs(title = "Scatter plot of MPG vs Weight",
       x = "Weight (1000 lbs)",
       y = "Miles per Gallon",
       color = "Cylinders") +
  theme_minimal()
p # Basic scatter plot (static)
plotly::ggplotly(p) # Convert to an interactive plot
```

The above interactive scatter plot allows:

- Hovering over points to see exact values.
- Zooming and panning dynamically.
- Interactive legend for highlighting different cylinder groups.

### Interactive scatter plot with customized tooltips

```
p <- mtcars |>
ggplot(aes(
  x = wt, y = mpg, color = factor(cyl),
  text = paste("Model:", rownames(mtcars), "<br>", # HTML tag <br> to initiate a new line
              "Cylinders:", cyl, "<br>",
              "Horsepower:", hp, "<br>",
              "Transmission:", ifelse(am == 0, "Automatic", "Manual"), "<br>",
              "Gear:", gear, "<br>",
              "Carburetors:", carb)
)) +
  geom_point(size = 3) +
  labs(title = "Scatter plot of MPG vs Weight",
       x = "Weight (1000 lbs)",
       y = "Miles per Gallon",
       color = "Cylinders") +
  theme_minimal()
plotly::ggplotly(
  p,
  tooltip = c("text", "x", "y") # Hiding color
)
```

### Interactive histogram

```
hist_plot <- ggplot(mtcars, aes(x = mpg, fill = factor(cyl))) +
  geom_histogram(alpha = 0.8, bins = 10) +
  labs(title = "Histogram of MPG by Cylinders",
       x = "Miles per Gallon",
       y = "Count",
       fill = "Cylinders") +
  theme_minimal()
plotly::ggplotly(hist_plot)
```

### Interactive boxplot

```
box_plot <- ggplot(mtcars, aes(x = factor(cyl), y = mpg, fill = factor(cyl))) +  
  geom_boxplot() +  
  labs(title = "MPG distribution by Cylinders",  
        x = "Cylinders",  
        y = "Miles per Gallon") +  
  theme_minimal()  
plotly::ggplotly(box_plot)
```

### Interactive line plot

```
line_plot <- ggplot(economics, aes(x = date, y = unemploy)) +  
  geom_line(color = "steelblue") +  
  labs(title = "Unemployment over Time",  
        x = "Year",  
        y = "Number of Unemployed (thousands)") +  
  theme_minimal()  
plotly::ggplotly(line_plot)
```

### Interactive jitter plot

```
p = starwars %>%  
  filter(!is.na(height) & !is.na(mass) & mass < 1000) %>%  
  ggplot(  
    aes(x = mass, y = height, color = sex)  
  ) +  
  geom_point() +  
  geom_jitter(  
    width= .2, # each point is randomly moved up to 0.2 units left or right.  
    height= .2, # each point is randomly moved up to 0.2 units up or down.  
    alpha = .2, # the transparency  
    color = "purple" # color for jittered points  
  ) +  
  labs(  
    title = "Height vs. Mass",  
    x = "Mass (kg)", y = "Height (cm)"  
  ) +  
  theme_bw()  
plotly::ggplotly(p)
```

### Interactive histogram with frequency polygon

```
p = starwars %>%  
  filter(!is.na(height)) %>%  
  ggplot(aes(x = height)) +  
  geom_histogram(bins = 10, fill = "steelblue", color = "black") +  
  geom_freqpoly(bins = 10, color = "orange", size = 1) +  
  labs(title = "Distribution of Character Heights",  
        x = "Height (cm)", y = "Count") +  
  theme_minimal()  
plotly::ggplotly(p)
```

### Interactive stacked bar plot

```
p = starwars %>%
  ggplot(aes(
    x = fct_rev(species), # Reverses the order of species to correct flipping
    fill = sex
  )) +
  geom_bar(position = "stack") + # position = "fill" or "stack"
  labs(title = "Stacked Bar Chart",
    x = "Species", y = "Count") +
  theme_minimal() +
  coord_flip()
plotly::ggplotly(p)
```

### Interactive density plot

```
p = starwars %>%
  filter(!is.na(mass) & !is.na(sex) & mass<1000) %>%
  ggplot(aes(x = mass, fill = sex)) +
  geom_density(alpha = 0.6) + # alpha controls the transparency
  labs(title = "Density Plot of Mass by sex",
    x = "Mass (kg)",
    y = "Density") +
  theme_minimal()
plotly::ggplotly(p)
```

### Interactive violin plot with a box plot inside

```
p = starwars %>%
  ggplot(aes(x = sex, y = height, fill = sex)) +
  geom_violin(alpha = 0.5) +
  geom_boxplot(width = 0.1) +
  labs(title = "Violin Plot with Box Plot",
    x = "sex", y = "Height (cm)") +
  theme_minimal()
plotly::ggplotly(p)
```

### Interactive heatmap

```
cor_df <- as.data.frame(cor(mtcars)) %>%
  rownames_to_column(var = "Var1") %>%
  pivot_longer(cols = -Var1, names_to = "Var2", values_to = "Correlation")
cor_df <- cor_df %>%
  mutate(Var2 = factor(Var2, levels = rev(sort(unique(Var2)))))
p = ggplot(cor_df, aes(Var1, Var2, fill = Correlation)) +
  geom_tile() +
  scale_fill_gradient(low = "white", high = "red") +
  labs(title = "Heatmap of mtcars Correlation Matrix",
    x = "Variable", y = "Variable") +
  theme_minimal()
plotly::ggplotly(p)
```

## plotly::plot\_ly: creating custom interactive plots from scratch

### Interactive scatter plot

```
plotly::plot_ly(  
  data = mtcars,  
  x = ~wt,  
  y = ~mpg,  
  type = "scatter", mode = "markers", # Scatter plot  
  color = ~factor(cyl),               # Color by cylinder (categorical)  
  marker = list(size = 10),           # Marker size  
  text = ~paste("Cylinders:", cyl,  
                "<br>MPG:", mpg,  
                "<br>Weight:", wt),    # Tooltip  
  hoverinfo = "text"                 # Show only custom text on hover  
) |> plotly::layout(  
  title = "Scatter plot of MPG vs Weight",  
  xaxis = list(title = "Weight (1000 lbs)"),  
  yaxis = list(title = "Miles per Gallon"),  
  legend = list(title = list(text = "Cylinders"))  
)
```

### Interactive histogram

```
plotly::plot_ly(  
  data = mtcars,  
  x = ~mpg,  
  color = ~factor(cyl),  
  type = "histogram",  
  nbinsx = 20,  
  opacity = 0.8  
) %>% plotly::layout(  
  title = "Histogram of MPG by Cylinders",  
  xaxis = list(title = "Miles per Gallon"),  
  yaxis = list(title = "Count"),  
  barmode = "stack", # stacked histogram  
  legend = list(title = list(text = "Cylinders"))  
)
```

### Interactive boxplot

```
plotly::plot_ly(  
  data = mtcars,  
  x = ~factor(cyl),  
  y = ~mpg,  
  color = ~factor(cyl),  
  type = "box"  
) %>% plotly::layout(  
  title = "MPG distribution by Cylinders",  
  xaxis = list(title = "Cylinders"),  
  yaxis = list(title = "Miles per Gallon"),  
  legend = list(title = list(text = "Cylinders"))  
)
```

## Interactive line plot

```
plotly::plot_ly(  
  data = economics,  
  x = ~date,  
  y = ~unemploy,  
  type = "scatter",  
  mode = "lines",  
  line = list(color = "steelblue")  
) %>% plotly::layout(  
  title = "Unemployment over Time",  
  xaxis = list(title = "Year"),  
  yaxis = list(title = "Number of Unemployed (thousands)")  
)
```

## Interactive stacked bar plot

```
starwars %>%  
  filter(!is.na(species), !is.na(sex)) %>%  
  count(species, sex) %>%  
  mutate(species = fct_rev(as.factor(species))) %>%  
  plotly::plot_ly(  
    x = ~n,  
    y = ~species,  
    color = ~sex,  
    type = "bar",  
    orientation = "h"  
  ) %>% plotly::layout(  
    bargroup = "stack",  
    title = "Stacked Bar Chart",  
    xaxis = list(title = "Count"),  
    yaxis = list(title = "Species"),  
    legend = list(title = list(text = "Sex")),  
    template = "plotly_white"  
  )
```

## Interactive violin plot with a box plot inside

```
starwars %>%  
  filter(!is.na(height), !is.na(sex)) |>  
  plotly::plot_ly(  
    x = ~sex,  
    y = ~height,  
    type = "violin",  
    split = ~sex,  
    box = list(visible = TRUE), # adds boxplot inside  
    meanline = list(visible = TRUE), # optional: shows mean  
    fillcolor = "rgba(100,100,255,0.5)", # semi-transparent fill  
    opacity = 0.5,  
    line = list(color = "black"),  
    showlegend = FALSE  
  ) %>% plotly::layout(  
    title = "Violin Plot with Box Plot",
```

```

    xaxis = list(title = "Sex"),
    yaxis = list(title = "Height (cm)",
    template = "plotly_white"
)

```

### Interactive heatmap

```

cor_df <- as.data.frame(cor(mtcars)) %>%
  rownames_to_column(var = "Var1") %>%
  pivot_longer(cols = -Var1, names_to = "Var2", values_to = "Correlation")
cor_df <- cor_df %>%
  mutate(Var2 = factor(Var2, levels = rev(sort(unique(Var2)))))
plotly::plot_ly(
  data = cor_df,
  x = ~Var1,
  y = ~Var2,
  z = ~Correlation,
  type = "heatmap",
  colors = c("white", "red"),
  colorbar = list(title = "Correlation")
) %>% plotly::layout(
  title = "Heatmap of mtcars Correlation Matrix",
  xaxis = list(title = "Variable"),
  yaxis = list(title = "Variable")
)

```

### Interactive 3D scatter plot

```

plotly::plot_ly(
  data = mtcars,
  x = ~wt,
  y = ~mpg,
  z = ~hp,
  type = "scatter3d",
  mode = "markers",
  color = ~factor(cyl)
)

```

### Interactive 3D surface plot—visualizing a bivariate function

```

x <- seq(-10, 10, length.out = 50)
y <- x
z <- outer(x, y, function(x, y) cos(sqrt(x^2 + y^2)))
plotly::plot_ly(
  x = ~x, y = ~y, z = ~z,
  type = "surface"
) %>% plotly::layout(title = "3D Surface Plot")

```

### Interactive geographic map: highlighting coordinates

```

df <- data.frame(
  city = c("New York", "London", "Tokyo"),

```

```

lat = c(40.7128, 51.5074, 35.6895),
lon = c(-74.0060, -0.1278, 139.6917)
)
plotly::plot_ly(
  data = df,
  type = "scattergeo",
  mode = "markers",
  lat = ~lat,
  lon = ~lon,
  text = ~city,
  marker = list(size = 10, color = "blue")
) %>% plotly::layout(
  geo = list(
    projection = list(type = "natural earth"), # "natural earth" or "orthographic"
    showland = TRUE
  ),
  title = "Cities on a Globe"
)

```

### Interactive geographic map: highlighting countries

```

plotly::plot_ly(
  type = "choropleth",
  locations = c("USA", "CAN", "AUS"), # ISO 3166-1 alpha-3 codes
  locationmode = "ISO-3",
  z = c(1,1,3), # c(1,2,3): means one color for each country
  colorscale = list(c(0, "lightgray"), c(1, "steelblue")), # Color scale
  showscale = F
) |> plotly::layout(
  geo = list(
    showframe = T,
    showcoastlines = TRUE,
    projection = list(type = "natural earth") # "natural earth" or "orthographic"
  ),
  title = ""
)

```

### Interactive geographic map: highlighting Wisconsin on a US Map

```

plotly::plot_ly(
  type = "choropleth",
  locations = c("WI", "AK", "MN"),
  locationmode = "USA-states",
  z = c(10000, 5000, 3000), # c(1,1): means one color for all
  colorscale = list(c(0, "lightgray"), c(1, "forestgreen")), # Color scale
  showscale = F
) |> plotly::layout(
  geo = list(
    scope = "usa",
    showlakes = F,
    lakecolor = "lightblue"
  ),
  title = "Wisconsin and Alaska"
)

```



)

## A dashboard combining multiple interactive plots into a single layout

```
p1 <- plotly::plot_ly(  
  mtcars,  
  x = ~mpg,  
  type = "histogram",  
  name = "MPG"  
)  
p2 <- plotly::plot_ly(  
  mtcars,  
  x = ~wt, y = ~mpg,  
  type = "scatter", mode = "markers",  
  name = "MPG vs Weight"  
)  
p3 <- plotly::plot_ly(  
  mtcars,  
  x = ~cyl, y = ~hp,  
  type = "box",  
  name = "HP by Cylinders"  
)  
plotly::subplot(  
  p1, p2, p3,  
  nrow = 1, margin = 0.05,  
  titleX = TRUE, titleY = TRUE  
) %>% plotly::layout(  
  title = "Mini Dashboard with plotly"  
)
```

## Summary: plotly::plot\_ly vs plotly::ggplotly

### Quick Comparison: plot\_ly() vs ggplotly()

Feature	plot_ly()	ggplotly()
Style	Build from scratch	Convert from ggplot2
Syntax	Plotly-native	ggplot2-based
Flexibility	High (fine control)	Moderate (tied to ggplot2)
Tooltips	Custom via <code>text</code> , <code>tooltip</code>	From <code>aes(text = ...)</code>
Layout control	Full via <code>layout()</code>	Partial via <code>theme()</code>
Best for	Dashboards, 3D, maps, full control	Quick interactivity for ggplot2 plots

### When to use which?

- Use `ggplotly` when:
  - You already have a `ggplot2` plot and want to add interactivity
  - You want a fast way to enable zoom, pan, hover, and tooltips.
  - You're more comfortable with `ggplot2` syntax.
- Use `plot_ly` when:
  - You want full control over every interactive aspect (like hover behavior, annotations, animations).
  - You're building web dashboards (e.g., with `shiny`) and want lightweight plots.
  - You're working with `plotly`-specific types like 3D plots and maps.

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## What is R Shiny

- An R package allowing users to create interactive web applications (apps) directly from R without the need for extensive web development knowledge
- References:
  - Mastering Shiny: <https://mastering-shiny.org/>
  - Cheatsheet: <https://raw.githubusercontent.com/rstudio/cheatsheets/main/shiny.pdf>

## Key features of R Shiny

- Create sophisticated interactive web apps directly from R
- Integrate seamlessly with other languages like HTML, CSS, and JavaScript
- Facilitate easy sharing of apps both online and internally
- Supports reactive programming for dynamic content

## Structure of a R Shiny app

- User interface (UI): defines the layout and appearance of the app
- Server: Contains R code and reactive expressions that generate the app's outputs based on user interactions

## The first R Shiny app: interactive bar plot of WorldPhones data

### Step 1

```
library(shiny)
# Use a fluid page layout
ui <- fluidPage()
# Define a server for the Shiny app
server <- function(input, output) {}
# Return a Shiny app object
shinyApp(ui = ui, server = server)
```

### Step 2

```
library(shiny)
# Use a fluid page layout
ui <- fluidPage(
  # Give the page a title
  titlePanel("Telephones by region")
)
# Define a server for the Shiny app
server <- function(input, output) {}
# Return a Shiny app object
shinyApp(ui = ui, server = server)
```

### Step 3

```
library(shiny)
# Use a fluid page layout
ui <- fluidPage(
  # Give the page a title
  titlePanel("Telephones by region"),
  # Layout a sidebar and main area
  sidebarLayout(
    # Define the sidebar
    sidebarPanel(
      selectInput(
        inputId = "region",
        label = "Region:",
        choices=colnames(WorldPhones)
      )
    ),
    # Create a spot for the main area
    mainPanel()
  )
)
# Define a server for the Shiny app
server <- function(input, output) {
}
# Return a Shiny app object
shinyApp(ui = ui, server = server)
```

### Step 4

```
library(shiny)
# Use a fluid page layout
ui <- fluidPage(
  # Give the page a title
  titlePanel("Telephones by region"),
  # Layout a sidebar and main area
  sidebarLayout(
    # Define the sidebar
    sidebarPanel(
      selectInput(
        inputId = "region",
        label = "Region:",
        choices=colnames(WorldPhones)
      )
    ),
    # Create a spot for the main area
    mainPanel(
      plotOutput("phonePlot")
    )
  )
)
# Define a server for the Shiny app
server <- function(input, output) {
  # Fill in the spot we created for a plot
```

```

output$phonePlot <- renderPlot(
  # Render a barplot
  barplot(
    WorldPhones[,input$region]*1000,
    main=input$region,
    ylab="Number of Telephones",
    xlab="Year"
  )
)
}
# Return a Shiny app object
shinyApp(ui = ui, server = server)

```

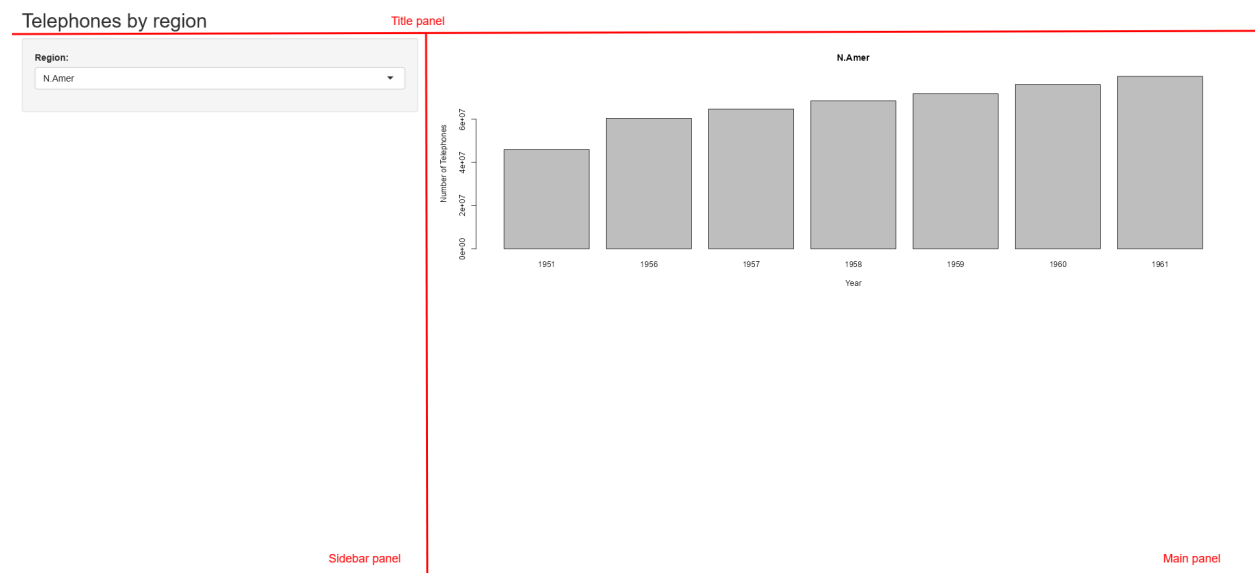


Figure 1: Three panels

## Step 5

```

library(shiny)
# Use a fluid page layout
ui <- fluidPage(
  # Give the page a title
  titlePanel("Telephones by region"),
  # Layout a sidebar and main area
  sidebarLayout(
    # Define the sidebar
    sidebarPanel(
      selectInput(
        inputId = "region",
        label = "Region:",
        choices=colnames(WorldPhones)
      )
    ),
    # Create a spot for the main area
  )
)

```

```

    mainPanel(
      plotOutput("phonePlot")
    )
  )
}
# Define a server for the Shiny app
server <- function(input, output) {
  # Fill in the spot we created for a plot
  output$phonePlot <- renderPlot(
    # Render a barplot
    barplot(
      WorldPhones[,input$region]*1000,
      main=input$region,
      ylab="Number of Telephones",
      xlab="Year"
    )
  )
}
# Return a Shiny app object
shinyApp(ui = ui, server = server)

```

## Step 6

```

library(shiny)
# Use a fluid page layout
ui <- fluidPage(
  # Give the page a title
  titlePanel("Telephones by region"),
  # Layout a sidebar and main area
  sidebarLayout(
    # Define the sidebar
    sidebarPanel(
      selectInput(
        inputId = "region",
        label = "Region:",
        choices=colnames(WorldPhones)
      ),
      helpText("Data from AT&T (1961) The World's Telephones.")
    ),
    # Create a spot for the main area
    mainPanel(
      plotOutput("phonePlot")
    )
  )
}
# Define a server for the Shiny app
server <- function(input, output) {
  # Fill in the spot we created for a plot
  output$phonePlot <- renderPlot(
    # Render a barplot
    barplot(
      WorldPhones[,input$region]*1000,
      main = input$region,

```

```

        ylab = "Number of Telephones",
        xlab = "Year"
      )
    )
  }
  # Return a Shiny app object
  shinyApp(ui = ui, server = server)

```

Step 7: if using bar plots generated via ggplot2

```

library(shiny)
library(tidyverse)
# Use a fluid page layout
ui <- fluidPage(
  # Give the page a title
  titlePanel("Telephones by region"),
  # Layout a sidebar and main area
  sidebarLayout(
    # Define the sidebar
    sidebarPanel(
      selectInput(
        inputId = "region",
        label = "Region:",
        choices=colnames(WorldPhones)
      ),
      helpText("Data from AT&T (1961) The World's Telephones.")
    ),
    # Create a spot for the main area
    mainPanel(
      plotOutput("phonePlot")
    )
  )
)
# Define a server for the Shiny app
server <- function(input, output) {
  # Fill in the spot we created for a plot
  output$phonePlot <- renderPlot(
    # Render a ggplot2 bar plot
    WorldPhones |>
      ggplot(aes(x = rownames(WorldPhones), y = WorldPhones[, input$region] * 1000)) +
      geom_bar(stat = "identity") +
      labs(
        title = input$region,
        x = "Year",
        y = "Number of Telephones"
      )
  )
}
# Return a Shiny app object
shinyApp(ui = ui, server = server)

```

Step 8: if using bar plots generated via `plot_ly`

```
library(shiny)
library(plotly)
# Use a fluid page layout
ui <- fluidPage(
  # Give the page a title
  titlePanel("Telephones by region"),
  # Layout a sidebar panel and main panel
  sidebarLayout(
    # Define the sidebar
    sidebarPanel(
      selectInput(
        inputId = "region",
        label = "Region:",
        choices=colnames(WorldPhones)
      ),
      helpText("Data from AT&T (1961) The World's Telephones.")
    ),
    # Create a spot for the main area
    mainPanel(
      plotlyOutput("phonePlot") # plotOutput -> plotlyOutput
    )
  )
)
# Define a server for the Shiny app
server <- function(input, output) {
  # Fill in the spot we created for a plot
  output$phonePlot <- renderPlotly( # renderPlot -> renderPlotly
    # Render a plot_ly barplot
    plot_ly(
      x = rownames(WorldPhones), # Years from row names
      y = WorldPhones[, input$region] * 1000, # Data for selected region, scaled
      type = "bar",
      name = input$region
    ) %>% layout(
      title = input$region,
      xaxis = list(title = "Year"),
      yaxis = list(title = "Number of Telephones")
    )
  )
}
# Return a Shiny app object
shinyApp(ui = ui, server = server)
```

The second R Shiny app: interactive plots of `agridat::beaven.barley` data

```
library(shiny)
library(tidyverse)

Barley <- as.data.frame(agridat::beaven.barley)
ui <- fluidPage(
  titlePanel("Barley Yield"),
```

```

sidebarLayout(
  sidebarPanel(
    selectInput(
      inputId = "gen", # Give the input a name "genotype"
      label = "1. Select genotype",
      choices = c(
        "A" = "a",
        "B" = "b",
        "C" = "c",
        "D" = "d",
        "E" = "e",
        "F" = "f",
        "G" = "g",
        "H" = "h"
      ),
      selected = "a"
    ),
    selectInput(
      inputId = "color",
      label = "2. Select the color of histogram frame",
      choices = c("blue", "green", "red", "purple", "grey"),
      selected = "grey"
    ),
    selectInput(
      inputId = "fill",
      label = "3. Select the color of histogram bins",
      choices = c("blue", "green", "red", "purple", "grey"),
      selected = "grey"
    ),
    sliderInput(
      inputId = "bin",
      label = "4. Select number of histogram bins",
      min = 1, max = 25, step = 1, round = T,
      value = 10 # Initial value
    ),
    textInput(
      inputId = "text",
      label = "4. Enter some text to be displayed",
      value = "" # Initial value
    )
  ),
  mainPanel(
    plotOutput("myhist"),
    tableOutput("mytable"),
    textOutput("mytext")
  )
)

server <- function(input, output) {
  output$myhist <- renderPlot(
    ggplot(Barley, aes(x = yield)) +
    geom_histogram(

```



```

    bins = input$bin, group=input$gen,
    data=Barley[Barley$gen == input$gen,],
    color = input$color,
    fill = input$fill
  )
)
output$mytext <- renderText(input$text)
output$mytable <- renderTable({
  Barley %>%
    filter(gen == input$gen) %>%
    summarise(
      "Mean" = mean(yield),
      "Median" = median(yield),
      "STDEV" = sd(yield),
      "Min" = min(yield),
      "Max" = max(yield)
    )
})
}

# Return a Shiny app object
shinyApp(ui = ui, server = server)

```

## The third R Shiny app: visualizing movie ratings from IMDb

<https://shiny.posit.co/r/getstarted/build-an-app/hello-shiny/getting-started.html>

```

library(shiny)
library(tidyverse)

# Get the data
# An .RData file is a file format used in R to save and store R objects
# (such as data 3 frames, lists, vectors, functions, or entire workspaces)
# E.g., use save.image(file = "workspace.RData") to save the entire workspace.

url <- "https://github.com/rstudio-education/shiny-course/raw/main/movies.RData"
destfile <- "movies.RData"
download.file(url, destfile) # save movies.RData in a temporary dir
load(destfile)

ui <- fluidPage(sidebarLayout(
  sidebarPanel(
    selectInput(
      inputId = "x",
      label = "X-axis:",
      choices = c(
        "IMDB rating" = "imdb_rating",
        "IMDB number of votes" = "imdb_num_votes",
        "Critics score" = "critics_score",
        "Audience score" = "audience_score",
        "Runtime" = "runtime"
      ),
      selected = "audience_score"
    ),
  ),

```

```

selectInput(
  inputId = "y",
  label = "Y-axis:",
  choices = c(
    "IMDB rating" = "imdb_rating",
    "IMDB number of votes" = "imdb_num_votes",
    "Critics score" = "critics_score",
    "Audience score" = "audience_score",
    "Runtime" = "runtime"
  ),
  selected = "critics_score"
),
selectInput(
  inputId = "z",
  label = "Color by:",
  choices = c(
    "Title type" = "title_type",
    "Genre" = "genre",
    "MPAA rating" = "mpaa_rating",
    "Critics rating" = "critics_rating",
    "Audience rating" = "audience_rating"
  ),
  selected = "mpaa_rating"
),
sliderInput(
  inputId = "opacity",
  label = "Opacity:",
  min = 0, max = 1,
  value = 0.5
),
dateRangeInput(
  inputId = "date",
  label = "Select dates:",
  start = min(as.Date(movies$thtr_rel_date)),
  end = max(as.Date(movies$thtr_rel_date)),
  min = min(as.Date(movies$thtr_rel_date)),
  max = max(as.Date(movies$thtr_rel_date)),
  startview = "year"
),
checkboxInput(
  inputId = "show_data",
  label = "Show data table",
  value = TRUE
),
downloadButton(outputId = "download_data", label = "Download Data")
),
mainPanel(
  plotOutput(outputId = "scatterplot"),
  plotOutput(outputId = "densityplot", height = 200),
  DT::dataTableOutput(outputId = "moviestable")
)
))

```

```

server <- function(input, output) {
  output$scatterplot <- renderPlot({
    movies |> filter(
      thtr_rel_date >= as.POSIXct(input$date[1]) &
      thtr_rel_date <= as.POSIXct(input$date[2])
    ) |> ggplot(
      aes(x = .data[[input$x]], y = .data[[input$y]], color = .data[[input$z]])
    ) +
    geom_point(alpha = input$opacity)
  })

  output$densityplot <- renderPlot({
    movies |> filter(
      thtr_rel_date >= as.POSIXct(input$date[1]) &
      thtr_rel_date <= as.POSIXct(input$date[2])
    ) |>
    ggplot(aes(x = .data[[input$x]])) +
    geom_density()
  })

  output$moviestable <- DT::renderDT({
    if(input$show_data == T){
      movies |> filter(
        thtr_rel_date >= as.POSIXct(input$date[1]) &
        thtr_rel_date <= as.POSIXct(input$date[2])
      ) |> DT::datatable(
        options = list(pageLength = 10), rownames = FALSE)
    }
  })

  output$download_data <- downloadHandler(
    filename = function() {
      paste("movies_filtered_", Sys.Date(), ".csv", sep = "")
    },
    content = function(file) {
      write.csv(
        movies |> filter(
          thtr_rel_date >= as.POSIXct(input$date[1]) &
          thtr_rel_date <= as.POSIXct(input$date[2])
        ),
        file,
        row.names = FALSE
      )
    }
  )
}

shinyApp(ui = ui, server = server)

```

## Reactive programming

- A programming paradigm that automatically updates outputs when inputs change, without you needing to write manual control flow logic.

- In Shiny, reactive programming is what enables your app to respond to user input and update UI elements in real time.
  - E.g., user adjusts a slider → a reactive expression recalculates → a plot/table/text output updates accordingly
- Key reactive building blocks in R Shiny

Function	Purpose
<code>input\$...</code>	Access values from UI inputs
<code>output\$...</code>	Assign reactive outputs to UI placeholders
<code>render*()</code>	Create outputs that react to input changes
<code>reactive()</code>	Define a reusable reactive expression (returns a value)
<code>observe()</code>	Perform side effects when inputs change (no return value)
<code>observeEvent()</code>	Trigger action when a specific input changes
<code>isolate()</code>	Prevent reactive tracking of an expression

- Use `reactive()` when you want to re-use a computation across multiple outputs

```
library(shiny)
library(tidyverse)

url <- "https://github.com/rstudio-education/shiny-course/raw/main/movies.RData"
destfile <- "movies.RData"
download.file(url, destfile) # save movies.RData in a temporary dir
load(destfile)

ui <- fluidPage(
  sidebarLayout(
    sidebarPanel(
      selectInput(
        inputId = "x",
        label = "X-axis:",
        choices = c(
          "IMDB rating" = "imdb_rating",
          "IMDB number of votes" = "imdb_num_votes",
          "Critics score" = "critics_score",
          "Audience score" = "audience_score",
          "Runtime" = "runtime"
        ),
        selected = "audience_score"
      ),
      selectInput(
        inputId = "y",
        label = "Y-axis:",
        choices = c(
          "IMDB rating" = "imdb_rating",
          "IMDB number of votes" = "imdb_num_votes",
          "Critics score" = "critics_score",
          "Audience score" = "audience_score",
          "Runtime" = "runtime"
        ),
        selected = "critics_score"
      ),
      selectInput(
```

```

    inputId = "z",
    label = "Color by:",
    choices = c(
      "Title type" = "title_type",
      "Genre" = "genre",
      "MPAA rating" = "mpaa_rating",
      "Critics rating" = "critics_rating",
      "Audience rating" = "audience_rating"
    ),
    selected = "mpaa_rating"
  ),
  sliderInput(
    inputId = "opacity",
    label = "Opacity:",
    min = 0, max = 1,
    value = 0.5
  ),
  dateRangeInput(
    inputId = "date",
    label = "Select dates:",
    start = min(as.Date(movies$thtr_rel_date)),
    end = max(as.Date(movies$thtr_rel_date)),
    min = min(as.Date(movies$thtr_rel_date)),
    max = max(as.Date(movies$thtr_rel_date)),
    startview = "year"
  ),
  checkboxInput(
    inputId = "show_data",
    label = "Show data table",
    value = TRUE
  ),
  downloadButton(outputId = "download_data", label = "Download Data")
),
mainPanel(
  plotOutput(outputId = "scatterplot"),
  plotOutput(outputId = "densityplot", height = 200),
  DT::dataTableOutput(outputId = "moviestable")
)
)
)

server <- function(input, output) {
  movies_filtered = reactive({
    movies |> filter(
      thtr_rel_date >= as.POSIXct(input$date[1]) &
      thtr_rel_date <= as.POSIXct(input$date[2])
    )
  })
  output$scatterplot <- renderPlot({
    movies_filtered() |> ggplot(
      aes(x = .data[[input$x]], y = .data[[input$y]], color = .data[[input$z]])
    ) +
    geom_point(alpha = input$opacity)
  })
}

```

```

})

output$densityplot <- renderPlot({
  movies_filtered() |>
    ggplot(aes(x = .data[[input$x]])) +
    geom_density()
})

output$moviestable <- DT::renderDT({
  if(input$show_data == T){
    movies_filtered() |> DT::datatable(
      options = list(pageLength = 10), rownames = FALSE)
  }
})

output$download_data <- downloadHandler(
  filename = function() {
    paste("movies_filtered_", Sys.Date(), ".csv", sep = "")
  },
  content = function(file) {
    write.csv(
      movies_filtered(),
      file,
      row.names = FALSE
    )
  }
)
}

shinyApp(ui = ui, server = server)

```

- `observe()`: react to real-time changes in inputs

```

library(shiny)
library(tidyverse)

url <- "https://github.com/rstudio-education/shiny-course/raw/main/movies.RData"
destfile <- "movies.RData"
download.file(url, destfile) # save movies.RData in a temporary dir
load(destfile)

ui <- fluidPage(
  sidebarLayout(
    sidebarPanel(
      selectInput(
        inputId = "x",
        label = "X-axis:",
        choices = c(
          "IMDB rating"           = "imdb_rating",
          "IMDB number of votes" = "imdb_num_votes",
          "Critics score"        = "critics_score",
          "Audience score"      = "audience_score",
          "Runtime"              = "runtime"
        )
      )
    )
  )
)

```

```

    selected = "audience_score"
  ),
  selectInput(
    inputId = "y",
    label = "Y-axis:",
    choices = c(
      "IMDB rating" = "imdb_rating",
      "IMDB number of votes" = "imdb_num_votes",
      "Critics score" = "critics_score",
      "Audience score" = "audience_score",
      "Runtime" = "runtime"
    ),
    selected = "critics_score"
  ),
  selectInput(
    inputId = "z",
    label = "Color by:",
    choices = c(
      "Title type" = "title_type",
      "Genre" = "genre",
      "MPAA rating" = "mpaa_rating",
      "Critics rating" = "critics_rating",
      "Audience rating" = "audience_rating"
    ),
    selected = "mpaa_rating"
  ),
  sliderInput(
    inputId = "opacity",
    label = "Opacity:",
    min = 0, max = 1,
    value = 0.5
  ),
  dateRangeInput(
    inputId = "date",
    label = "Select dates:",
    start = min(as.Date(movies$thtr_rel_date)),
    end = max(as.Date(movies$thtr_rel_date)),
    min = min(as.Date(movies$thtr_rel_date)),
    max = max(as.Date(movies$thtr_rel_date)),
    startview = "year"
  ),
  checkboxInput(
    inputId = "show_data",
    label = "Show data table",
    value = TRUE
  ),
  downloadButton(outputId = "download_data", label = "Download Data")
),
mainPanel(
  plotOutput(outputId = "scatterplot"),
  plotOutput(outputId = "densityplot", height = 200),
  DT::dataTableOutput(outputId = "moviestable")
)

```

```

)
)

server <- function(input, output) {
  observe({
    message(
      paste("You picked data from", as.POSIXct(input$date[1]), "through", as.POSIXct(input$date[2]))
    )
  })
  movies_filtered = reactive({
    movies |> filter(
      thtr_rel_date >= as.POSIXct(input$date[1]) &
      thtr_rel_date <= as.POSIXct(input$date[2])
    )
  })
  output$scatterplot <- renderPlot({
    movies_filtered() |> ggplot(
      aes(x = .data[[input$x]], y = .data[[input$y]], color = .data[[input$z]])
    ) +
    geom_point(alpha = input$opacity)
  })

  output$densityplot <- renderPlot({
    movies_filtered() |>
    ggplot(aes(x = .data[[input$x]])) +
    geom_density()
  })

  output$moviestable <- DT::renderDT({
    if(input$show_data == T){
      movies_filtered() |> DT::datatable(
        options = list(pageLength = 10), rownames = FALSE)
    }
  })

  output$download_data <- downloadHandler(
    filename = function() {
      paste("movies_filtered_", Sys.Date(), ".csv", sep = "")
    },
    content = function(file) {
      write.csv(
        movies_filtered(),
        file,
        row.names = FALSE
      )
    }
  )
}

shinyApp(ui = ui, server = server)

```

- `observeEvent()`: react to discrete events



```

library(shiny)
library(tidyverse)

url <- "https://github.com/rstudio-education/shiny-course/raw/main/movies.RData"
destfile <- "movies.RData"
download.file(url, destfile) # save movies.RData in a temporary dir
load(destfile)

ui <- fluidPage(
  sidebarLayout(
    sidebarPanel(
      selectInput(
        inputId = "x",
        label = "X-axis:",
        choices = c(
          "IMDB rating" = "imdb_rating",
          "IMDB number of votes" = "imdb_num_votes",
          "Critics score" = "critics_score",
          "Audience score" = "audience_score",
          "Runtime" = "runtime"
        ),
        selected = "audience_score"
      ),
      selectInput(
        inputId = "y",
        label = "Y-axis:",
        choices = c(
          "IMDB rating" = "imdb_rating",
          "IMDB number of votes" = "imdb_num_votes",
          "Critics score" = "critics_score",
          "Audience score" = "audience_score",
          "Runtime" = "runtime"
        ),
        selected = "critics_score"
      ),
      selectInput(
        inputId = "z",
        label = "Color by:",
        choices = c(
          "Title type" = "title_type",
          "Genre" = "genre",
          "MPAA rating" = "mpaa_rating",
          "Critics rating" = "critics_rating",
          "Audience rating" = "audience_rating"
        ),
        selected = "mpaa_rating"
      ),
      sliderInput(
        inputId = "opacity",
        label = "Opacity:",
        min = 0, max = 1,
        value = 0.5
      ),

```

```

    dateRangeInput(
      inputId = "date",
      label = "Select dates:",
      start = min(as.Date(movies$thtr_rel_date)),
      end = max(as.Date(movies$thtr_rel_date)),
      min = min(as.Date(movies$thtr_rel_date)),
      max = max(as.Date(movies$thtr_rel_date)),
      startview = "year"
    ),
    checkboxInput(
      inputId = "show_data",
      label = "Show data table",
      value = TRUE
    ),
    downloadButton(
      outputId = "download_data",
      label = "Download Data"
    )
  ),
  mainPanel(
    plotOutput(outputId = "scatterplot"),
    plotOutput(outputId = "densityplot", height = 200),
    DT::dataTableOutput(outputId = "moviestable")
  )
)

server <- function(input, output) {
  observeEvent(
    eventExpr = input$x,
    handlerExpr = {
      showNotification(paste("You selected", input$x, "as the x-axis."))
    }, ignoreInit = TRUE)
  observeEvent(
    eventExpr = input$y,
    handlerExpr = {
      showNotification(paste("You selected", input$y, "as the y-axis."))
    }, ignoreInit = TRUE)
  movies_filtered = reactive({
    movies |> filter(
      thtr_rel_date >= as.POSIXct(input$date[1]) &
      thtr_rel_date <= as.POSIXct(input$date[2])
    )
  })
  output$scatterplot <- renderPlot({
    movies_filtered() |> ggplot(
      aes(x = .data[[input$x]], y = .data[[input$y]], color = .data[[input$z]])
    ) +
    geom_point(alpha = input$opacity)
  })
  output$densityplot <- renderPlot({
    movies_filtered() |>

```

```

    ggplot(aes(x = .data[[input$x]])) +
    geom_density()
  })

output$moviestable <- DT::renderDT({
  if(input$show_data == T){
    movies_filtered() |> DT::datatable(
      options = list(pageLength = 10), rownames = FALSE)
  }
})

output$download_data <- downloadHandler(
  filename = function() {
    paste("movies_filtered_", Sys.Date(), ".csv", sep = "")
  },
  content = function(file) {
    write.csv(
      movies_filtered(),
      file,
      row.names = FALSE
    )
  }
)
}

shinyApp(ui = ui, server = server)

```

- `isolate()`: read inputs without triggering automatic reactivity

```

library(shiny)
library(tidyverse)

url <- "https://github.com/rstudio-education/shiny-course/raw/main/movies.RData"
destfile <- "movies.RData"
download.file(url, destfile) # save movies.RData in a temporary dir
load(destfile)

ui <- fluidPage(
  sidebarLayout(
    sidebarPanel(
      selectInput(
        inputId = "x",
        label = "X-axis:",
        choices = c(
          "IMDB rating" = "imdb_rating",
          "IMDB number of votes" = "imdb_num_votes",
          "Critics score" = "critics_score",
          "Audience score" = "audience_score",
          "Runtime" = "runtime"
        ),
        selected = "audience_score"
      ),
      selectInput(
        inputId = "y",

```

```

label = "Y-axis:",
choices = c(
  "IMDB rating" = "imdb_rating",
  "IMDB number of votes" = "imdb_num_votes",
  "Critics score" = "critics_score",
  "Audience score" = "audience_score",
  "Runtime" = "runtime"
),
selected = "critics_score"
),
selectInput(
  inputId = "z",
  label = "Color by:",
  choices = c(
    "Title type" = "title_type",
    "Genre" = "genre",
    "MPAA rating" = "mpaa_rating",
    "Critics rating" = "critics_rating",
    "Audience rating" = "audience_rating"
  ),
  selected = "mpaa_rating"
),
sliderInput(
  inputId = "opacity",
  label = "Opacity:",
  min = 0, max = 1,
  value = 0.5
),
dateRangeInput(
  inputId = "date",
  label = "Select dates:",
  start = min(as.Date(movies$thtr_rel_date)),
  end = max(as.Date(movies$thtr_rel_date)),
  min = min(as.Date(movies$thtr_rel_date)),
  max = max(as.Date(movies$thtr_rel_date)),
  startview = "year"
),
checkboxInput(
  inputId = "show_data",
  label = "Show data table",
  value = TRUE
),
actionButton(
  inputId = "go",
  label = "Generate"
),
br(), # initiate a newline
downloadButton(
  outputId = "download_data",
  label = "Download Data"
),
),
mainPanel(

```

```

    plotOutput(outputId = "scatterplot"),
    plotOutput(outputId = "densityplot", height = 200),
    DT::dataTableOutput(outputId = "moviestable")
  )
)
)

server <- function(input, output) {
  observeEvent(
    eventExpr = input$go,
    handlerExpr = {
      movies_filtered = reactive({
        movies |> filter(
          thtr_rel_date >= as.POSIXct(isolate(input$date[1])) &
          thtr_rel_date <= as.POSIXct(isolate(input$date[2]))
        )
      })
      output$scatterplot <- renderPlot({
        movies_filtered() |> ggplot(
          aes(x = .data[[isolate(input$x)]], y = .data[[isolate(input$y)]], color = .data[[isolate(input$color)]])
        ) +
        geom_point(alpha = isolate(input$opacity))
      })
      output$densityplot <- renderPlot({
        movies_filtered() |>
        ggplot(aes(x = .data[[isolate(input$x)]])) +
        geom_density()
      })
      output$moviestable <- DT::renderDT({
        if(input$show_data == T){
          movies_filtered() |> DT::datatable(
            options = list(pageLength = 10), rownames = FALSE)
        }
      })
    }
  )
  output$download_data <- downloadHandler(
    filename = function() {
      paste("movies_filtered_", Sys.Date(), ".csv", sep = "")
    },
    content = function(file) {
      write.csv(
        movies_filtered(),
        file,
        row.names = FALSE
      )
    }
  )
}

shinyApp(ui = ui, server = server)

```

## More R Shiny input widgets

<https://raw.githubusercontent.com/rstudio/cheatsheets/main/shiny.pdf>

---

### bslib for a customized look

- bslib is an R package that enables you to customize the look and feel of Shiny apps and R Markdown documents using Bootstrap themes (pre-designed website templates built using the Bootstrap framework, a popular HTML, CSS, and JavaScript framework for responsive web development)

```
library(shiny)
library(tidyverse)
library(bslib)

url <- "https://github.com/rstudio-education/shiny-course/raw/main/movies.RData"
destfile <- "movies.RData"
download.file(url, destfile) # save movies.RData in a temporary dir
load(destfile)

ui <- fluidPage(
  theme = bs_theme(
    version = 5, # Bootstrap theme version (4 or 5)
    bootswatch = "cosmo", # Prebuilt Bootstrap themes; available themes at
    # print(bootswatch_themes(version = "5")); previews at
    # bs_theme_preview(bs_theme(bootswatch = "superhero"))
    primary = "#198754", # Color; available colors at
    # https://rstudio.github.io/bslib/articles/bs4-variables/index.html
    # https://rstudio.github.io/bslib/articles/bs5-variables/index.html
    base_font = font_google("Special Gothic Expanded One"), # available fonts at
    # https://fonts.google.com
    heading_font = font_google("Merriweather"),
    code_font = font_google("Fira Code")
  ),
  sidebarLayout(
    sidebarPanel(
      selectInput(
        inputId = "x",
        label = "X-axis:",
        choices = c(
          "IMDB rating" = "imdb_rating",
          "IMDB number of votes" = "imdb_num_votes",
          "Critics score" = "critics_score",
          "Audience score" = "audience_score",
          "Runtime" = "runtime"
        )
      ),
      selected = "audience_score"
    ),
    selectInput(
      inputId = "y",
      label = "Y-axis:",
      choices = c(
        "IMDB rating" = "imdb_rating",
        "IMDB number of votes" = "imdb_num_votes",
```

```

        "Critics score"      = "critics_score",
        "Audience score"   = "audience_score",
        "Runtime"           = "runtime"
    ),
    selected = "critics_score"
),
selectInput(
  inputId = "z",
  label = "Color by:",
  choices = c(
    "Title type" = "title_type",
    "Genre" = "genre",
    "MPAA rating" = "mpaa_rating",
    "Critics rating" = "critics_rating",
    "Audience rating" = "audience_rating"
  ),
  selected = "mpaa_rating"
),
sliderInput(
  inputId = "opacity",
  label = "Opacity:",
  min = 0, max = 1,
  value = 0.5
),
dateRangeInput(
  inputId = "date",
  label = "Select dates:",
  start = min(as.Date(movies$thtr_rel_date)),
  end = max(as.Date(movies$thtr_rel_date)),
  min = min(as.Date(movies$thtr_rel_date)),
  max = max(as.Date(movies$thtr_rel_date)),
  startview = "year"
),
checkboxInput(
  inputId = "show_data",
  label = "Show data table",
  value = TRUE
),
actionButton(
  inputId = "go",
  label = "Generate"
),
br(), # initiate a newline
downloadButton(
  outputId = "download_data",
  label = "Download Data"
),
),
mainPanel(
  plotOutput(outputId = "scatterplot"),
  plotOutput(outputId = "densityplot", height = 200),
  DT::dataTableOutput(outputId = "moviestable")
)

```

```

)
)

server <- function(input, output) {
  observeEvent(
    eventExpr = input$go,
    handlerExpr = {
      movies_filtered = reactive({
        movies |> filter(
          thtr_rel_date >= as.POSIXct(isolate(input$date[1])) &
          thtr_rel_date <= as.POSIXct(isolate(input$date[2]))
        )
      })
      output$scatterplot <- renderPlot({
        movies_filtered() |> ggplot(
          aes(
            x = .data[[isolate(input$x)]],
            y = .data[[isolate(input$y)]],
            color = .data[[isolate(input$z)]]
          )
        ) +
        geom_point(alpha = isolate(input$opacity))
      })
      output$densityplot <- renderPlot({
        movies_filtered() |>
        ggplot(aes(x = .data[[isolate(input$x)]])) +
        geom_density()
      })
      output$moviestable <- DT::renderDT({
        if(input$show_data == T){
          movies_filtered() |> DT::datatable(
            options = list(pageLength = 10), rownames = FALSE)
        }
      })
      output$download_data <- downloadHandler(
        filename = function() {
          paste("movies_filtered_", Sys.Date(), ".csv", sep = "")
        },
        content = function(file) {
          write.csv(
            movies_filtered(),
            file,
            row.names = FALSE
          )
        }
      )
    }
  )
}

shinyApp(ui = ui, server = server)

```



## Sharing R Shiny apps as webpages

- User-friendly: local installation of R NOT required for users
- Still a bit sticking: depends on intended audience, required computing power, number of expected users, ...
- shinyapps.io
  - <https://www.shinyapps.io/>
  - Posit’s hosting service with different plans
    - \* Free plan limited to 5 apps, 25 active hours per month
- Shiny server
  - <https://posit.co/download/shiny-server/>
  - Building a server by yourself to host Shiny apps (free, open source)

## Deploying an R Shiny app on shinyapps.io

- Sign Up at <https://www.shinyapps.io> with your email or GitHub account.
- Install `rsconnect` package locally.
- Create an R Script including the source code of your app.
- Open the R Script in RStudio.
- Test your app locally by clicking the “**Run**” button (upper-right).
- Click the “**Publish**” button (upper-right), choose shinyapps.io as the server and follow prompts.
  - Go to your shinyapps.io account and copy the name, token and secret for authentication.
- R will upload your app and provide a unique public URL
- Updated when you republish