

FE8828 Programming Web Applications in Finance

- Session 4 -

Data Visualization and EDA

Shiny/3: Advanced

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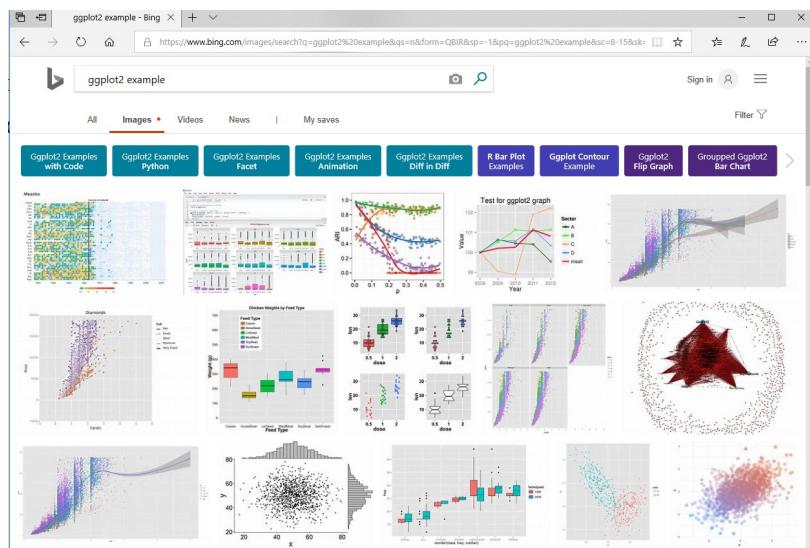
Lecture 8: Data Visualization and EDA

- `library(ggplot)`, author Hadley Wickham. First release on June 10, 2007.
- gg stands for “Grammar of Graphics”

<https://qz.com/1007328/all-hail-ggplot2-the-code-powering-all-those-excellent-charts-is-10-years-old/>



ggplot2 Examples



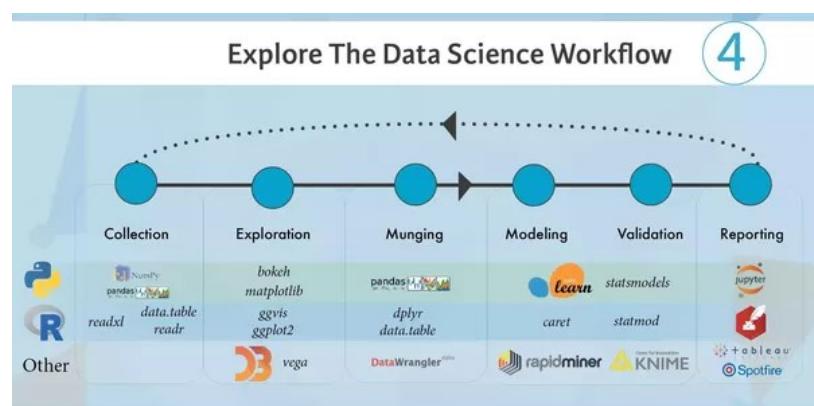
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Why do we need ggplot?

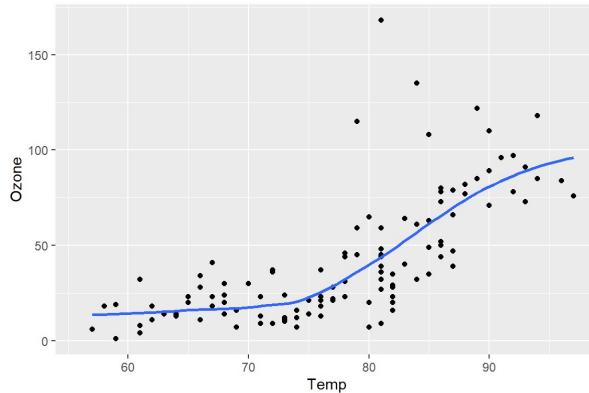
It's part of the exploration of the data via visualization.



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ggplot system

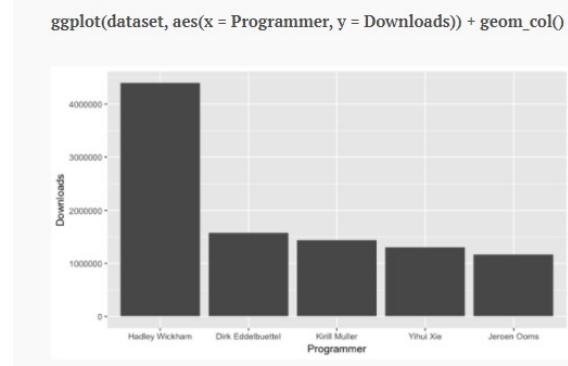
```
# library(ggplot2)
ggplot(airquality, aes(Temp, Ozone)) +
  geom_point() +
  geom_smooth(method = "loess", se = FALSE)
## Warning: Removed 37 rows containing non-finite values (stat_smooth).
## Warning: Removed 37 rows containing missing values (geom_point).
```



Syntax of ggplot

- Definition of data + Definitions of layers

```
ggplot(data = <DATA>, ...) +
<GEOM_FUNCTION>(mapping = aes(<MAPPINGS>))
```



Syntax of ggplot

- For example, `geom_point()` is for points, `geom_line()` is for line, `geom_smooth()` for smoothed line.
- The definition of data will pass down to the layers. But layers can have its own data.
- Put the + sign in the end of the line, not the beginning of the line.

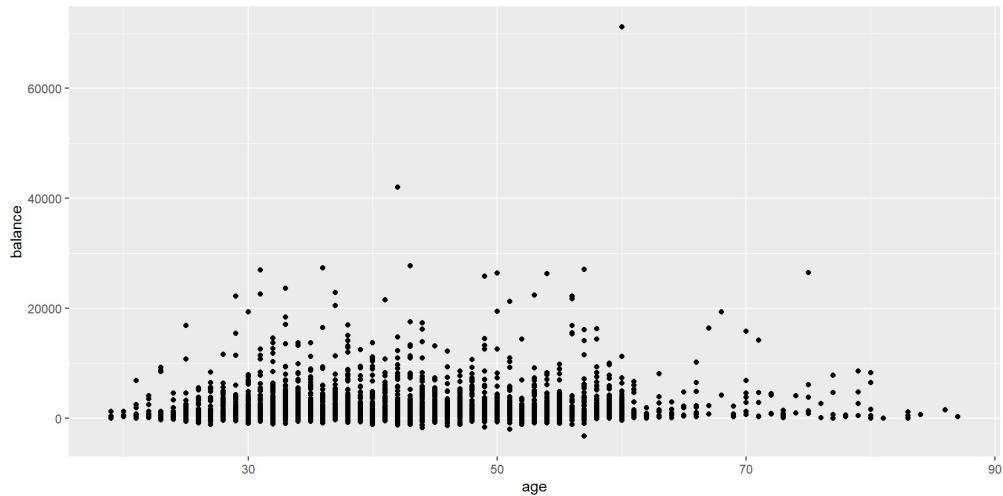
```
ggplot(data = d1, ...) +
  geom_point() + # this would get data = d1
  geom_point(data = d2, ...) # this would get data = d2
```

- Below would result in error

```
ggplot(data = <DATA>, ...)
+ <GEOM_FUNCTION>(mapping = aes(<MAPPINGS>))
```

Simply plot x and y

```
ggplot(bank, aes(age, balance)) + geom_point()
```



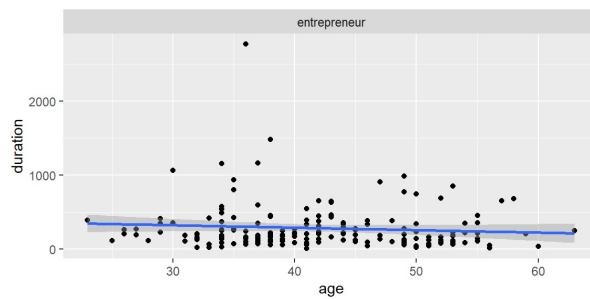
aes and aes_string

If you don't know the column name, use `aes_string` to pass variable name as string/character.

```
ggplot(bank, aes_string("age", "balance", color = "job")) + geom_point()
```

Example of `aes_string`

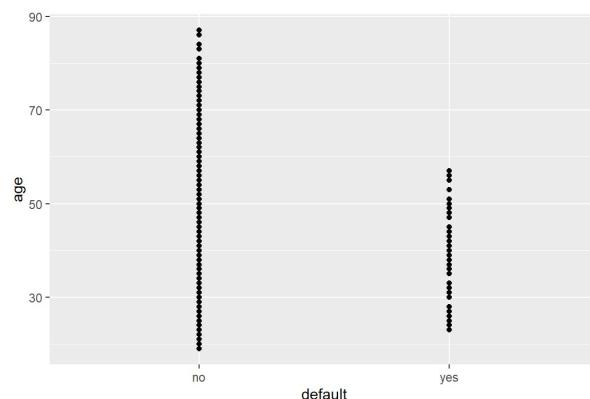
```
# in a Shiny app
selectInput("column", "col", choices = c("balance", "duration"))
plot_bank("age", input$col)
```



For non-numeric data: default and age

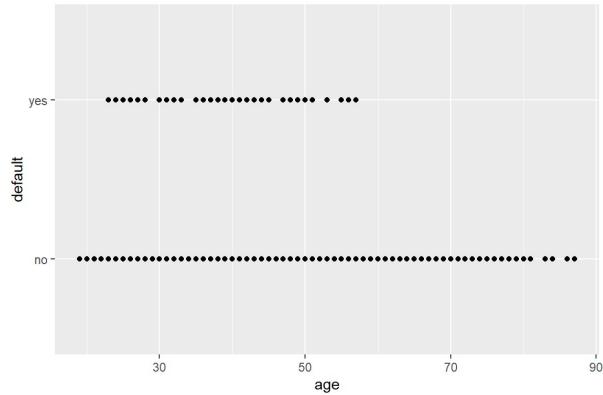
```
ggplot(bank, aes(default, age)) + geom_point()
ggplot(bank, aes(age, default)) + geom_point()
ggplot(bank, aes(job, age)) + geom_point()
```

```
ggplot(bank, aes(default, age)) + geom_point()
```



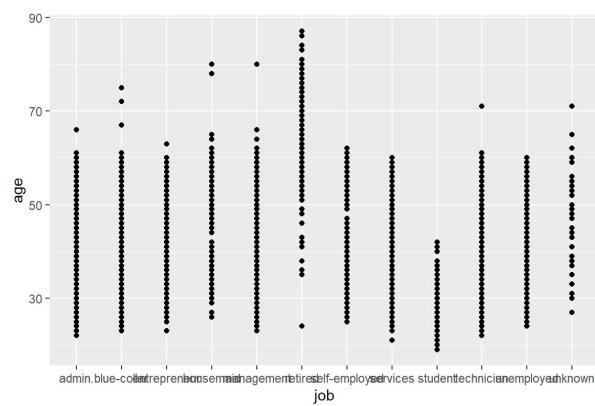
For non-numeric data: age and default (make it landscape)

```
ggplot(bank, aes(age, default)) + geom_point()
```



For non-numeric data: job and age

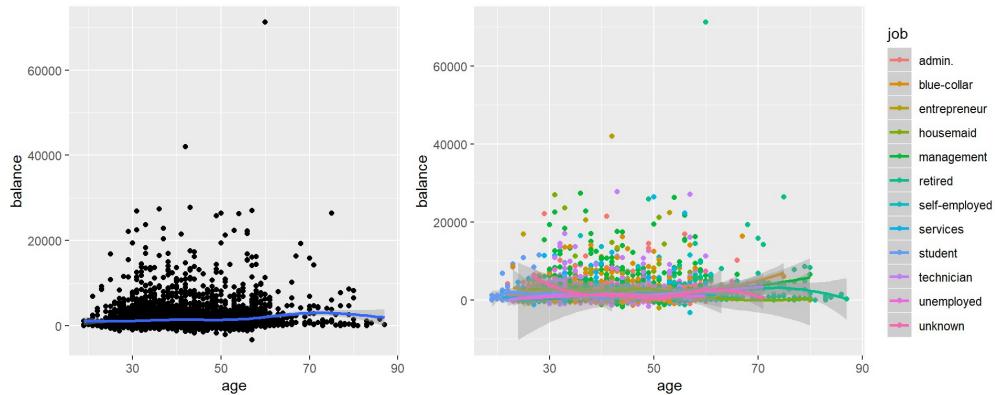
```
ggplot(bank, aes(job, age)) + geom_point()
```



Add 2nd geometry

```
ggplot(bank, aes(age, balance)) + geom_point() + geom_smooth()
ggplot(bank, aes(age, balance, color = job)) + geom_point() + geom_smooth()
```

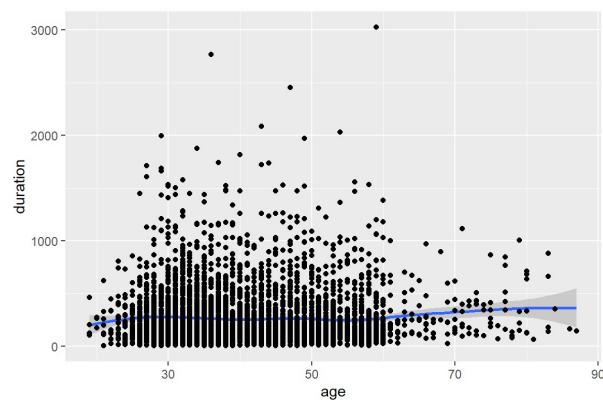
```
## `geom_smooth()` `using method = 'gam' and formula 'y ~ s(x, bs = "cs")'
## `geom_smooth()` `using method = 'loess' and formula 'y ~ x'
```



Pass aes down

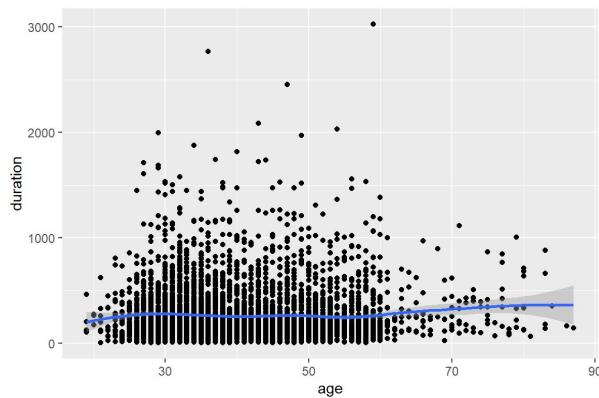
`geom_*` functions has a default parameter of `inherit.aes = T`.

```
ggplot(bank, aes(x = age, y = duration)) +
  geom_smooth() # same as geom_smooth(aes(x = age, y = duration))
  geom_point() # same as geom_point(aes(x = age, y = duration))
## `geom_smooth()` `using method = 'gam' and formula 'y ~ s(x, bs = "cs")'
```



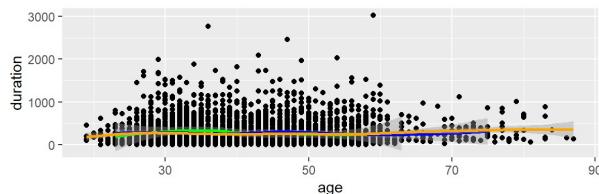
Pass aes down

```
# This is equivalent to below. But this is a bit repeating.
ggplot(bank) +
  geom_point(aes(x = age, y = duration)) +
  geom_smooth(aes(x = age, y = duration))
## `geom_smooth()` `using method = 'gam' and formula 'y ~ s(x, bs = "cs")'
```



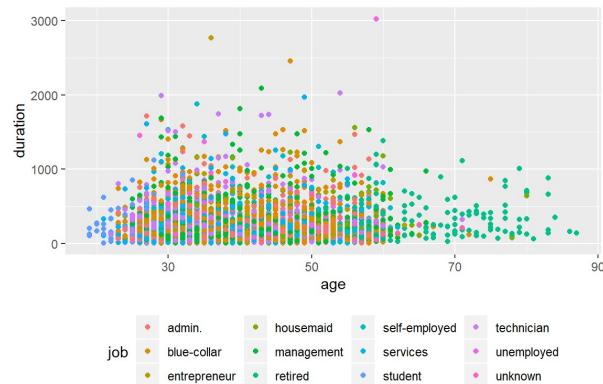
Pass aes down

```
# But repeating is useful sometimes.
# we can do specify different data and aes for different geom_* functions.
ggplot(bank) +
  geom_point(aes(x = age, y = duration)) +
  geom_smooth(data = dplyr::filter(bank, job == "entrepreneur"),
              aes(x = age, y = duration), color = "green") +
  geom_smooth(data = dplyr::filter(bank, job == "blue-collar"),
              aes(x = age, y = duration), color = "blue") +
  geom_smooth(data = dplyr::filter(bank, job != "entrepreneur"),
              aes(x = age, y = duration), color = "orange")
## `geom_smooth()` `using method = 'loess' and formula 'y ~ x'
## `geom_smooth()` `using method = 'loess' and formula 'y ~ x'
## `geom_smooth()` `using method = 'gam' and formula 'y ~ s(x, bs = "cs")'
```



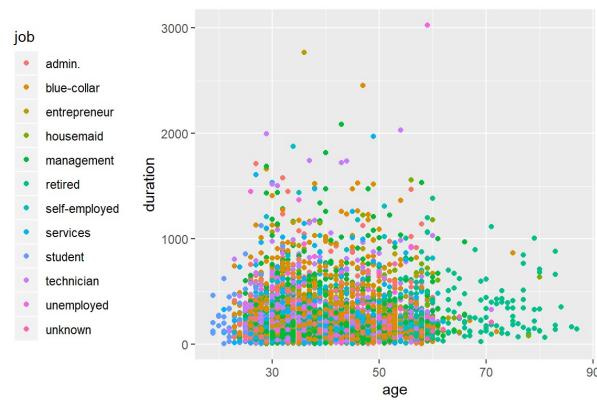
Adjustment: legend bottom

```
# adjust legend position
ggplot(bank, aes(x = age, y = duration, color = job)) +
  geom_point() +
  theme(legend.position="bottom")
```



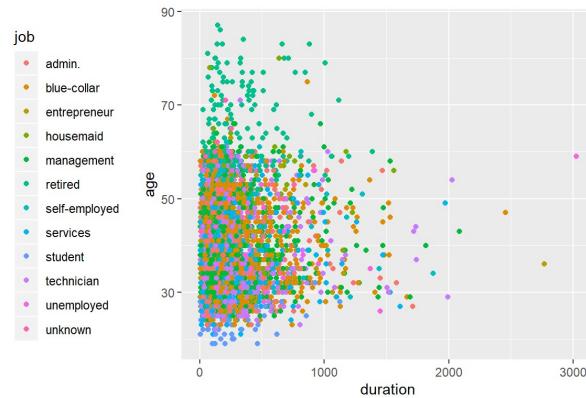
Adjustment: legend left

```
# legend to the left
ggplot(bank, aes(x = age, y = duration, color = job)) +
  geom_point() +
  theme(legend.position="left")
```



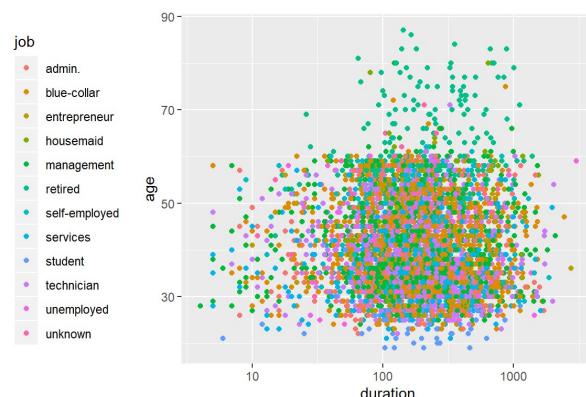
Adjustment: coordinate flip

```
# Flip the x and y axis
# Different feeling?
ggplot(bank, aes(x = age, y = duration, color = job)) +
  geom_point() +
  theme(legend.position="left") +
  coord_flip()
```



Adjustment: log scale

```
# Make y as log scaled.
# Note that before flip, x is y, so we use scale_y_log10()
ggplot(bank, aes(x = age, y = duration, color = job)) +
  geom_point() +
  theme(legend.position="left") +
  coord_flip() +
  scale_y_log10()
```



Each + is a layer

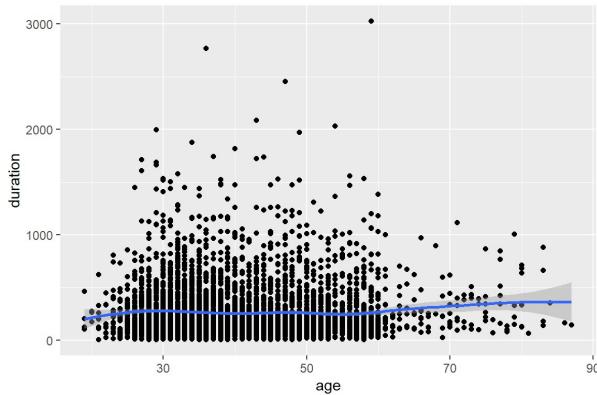
```
# Nearly empty chart.
g <- ggplot(bank, aes(x = age, y = duration))
# This is almost empty
g <- ggplot(bank)
# This is really empty.
g <- ggplot()
```



Combine g with layers

```
ggplot(bank, aes(x = age, y = duration)) +
  geom_point() + geom_smooth()
```

```
# This is equivalent to above
g <- ggplot(bank, aes(x = age, y = duration))
g + geom_point() + geom_smooth()
## `geom_smooth()` `using method = 'gam' and formula 'y ~ s(x, bs = "cs")'
```



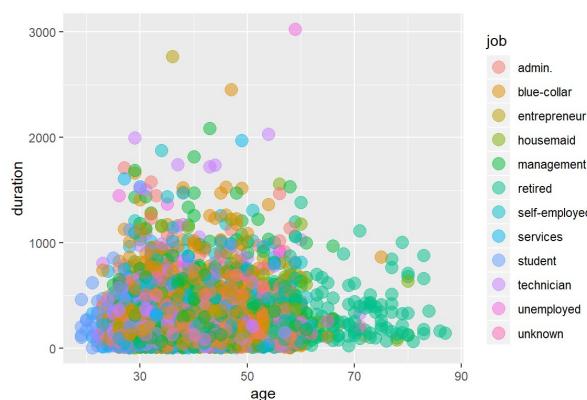
g can be re-used.

- g can be re-used. It's good to be used when we want to exploratory data and try to plot many figures.
- Fixed a few variables in `g <- ggplot(data, aes(...))`.
- Use `g + geom_XXX()` to find the best representation for the relationship.

```
g + geom_point() + geom_smooth(method = "lm") + facet_grid(. ~ job)
g + geom_point(color = "steelblue", size = 4, alpha = 1/2)
g + geom_point(aes(color = job), size = 4, alpha = 1/2)
g + geom_point() + geom_point(aes(color = job), size = 4, alpha = 1/2)
```

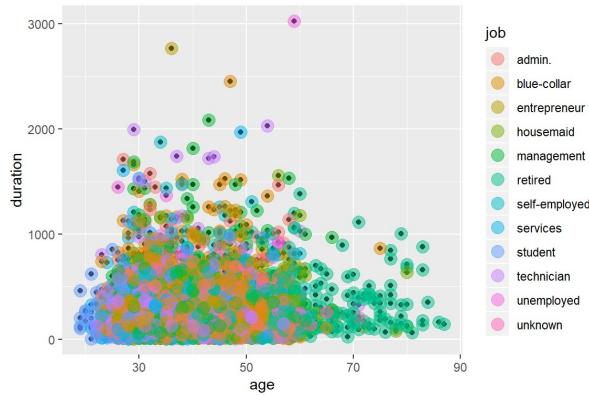
g: mix and match: which figure?

```
g + geom_point() + geom_smooth(method = "lm") + facet_grid(. ~ job)
g + geom_point(color = "steelblue", size = 4, alpha = 1/2)
g + geom_point(aes(color = job), size = 4, alpha = 1/2)
g + geom_point() + geom_point(aes(color = job), size = 4, alpha = 1/2)
```



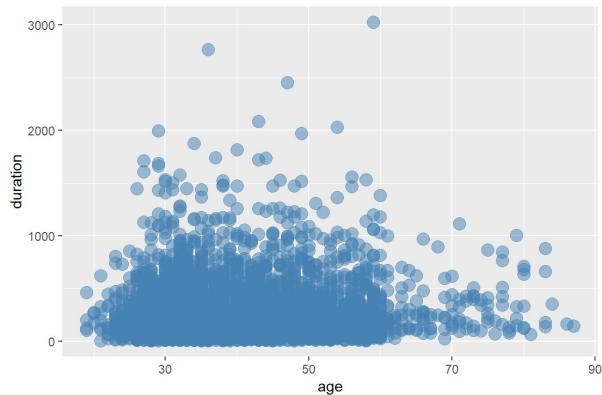
g: mix and match: which figure?

```
g + geom_point() + geom_smooth(method = "lm") + facet_grid(. ~ job)
g + geom_point(color = "steelblue", size = 4, alpha = 1/2)
g + geom_point(aes(color = job), size = 4, alpha = 1/2)
g + geom_point() + geom_point(aes(color = job), size = 4, alpha = 1/2)
```



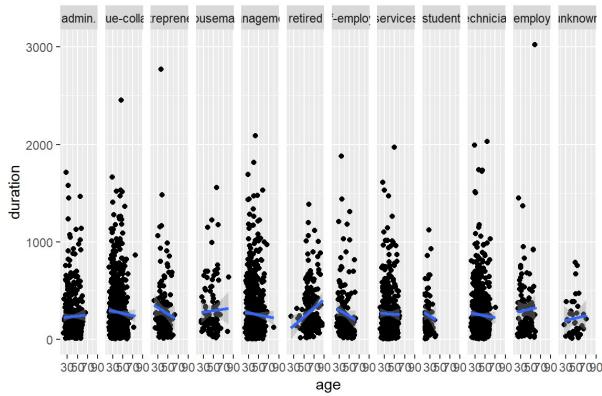
g: mix and match: which figure?

```
g + geom_point() + geom_smooth(method = "lm") + facet_grid(. ~ job)
g + geom_point(color = "steelblue", size = 4, alpha = 1/2)
g + geom_point(aes(color = job), size = 4, alpha = 1/2)
g + geom_point() + geom_point(aes(color = job), size = 4, alpha = 1/2)
```



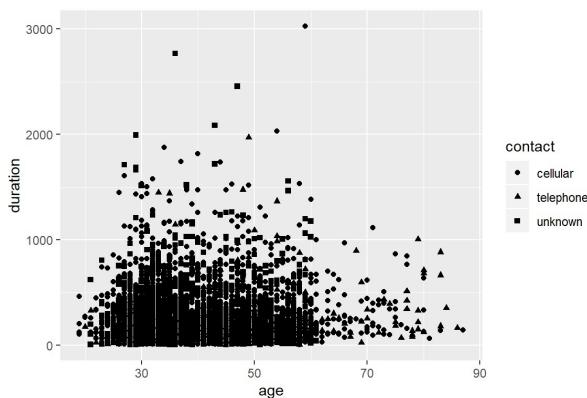
g: mix and match: which figure?

```
# g + geom_point() + geom_smooth(method = "lm") + facet_grid(. ~ job)
g + geom_point(color = "steelblue", size = 4, alpha = 1/2)
g + geom_point(aes(color = job), size = 4, alpha = 1/2)
g + geom_point() + geom_point(aes(color = job), size = 4, alpha = 1/2)
```



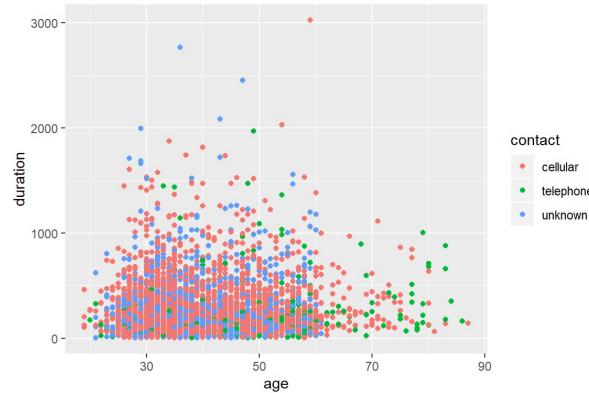
Differentiate groups - shape

```
# Use shape
ggplot(bank) +
  geom_point(aes(age, duration, shape = contact))
```



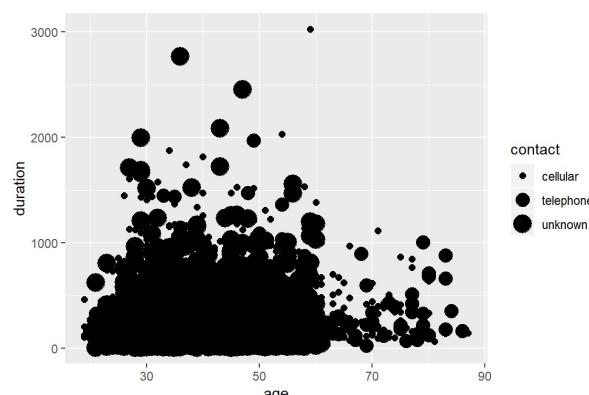
Differentiate groups - color

```
# Use color
ggplot(bank) +
  geom_point(aes(age, duration, color = contact))
```



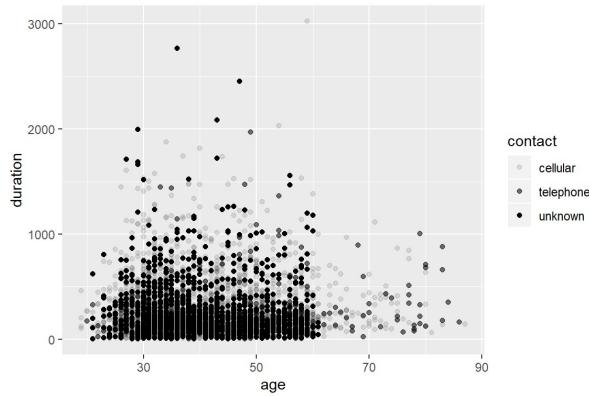
Differentiate groups - size

```
# Use size
ggplot(bank) +
  geom_point(aes(age, duration, size = contact))
## Warning: Using size for a discrete variable is not advised.
```



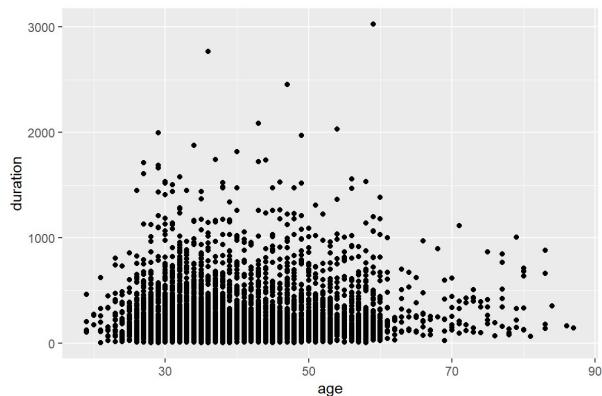
Differentiate groups - alpha

```
# Use alpha - transparency
ggplot(bank) +
  geom_point(aes(age, duration, alpha = contact))
## Warning: Using alpha for a discrete variable is not advised.
```



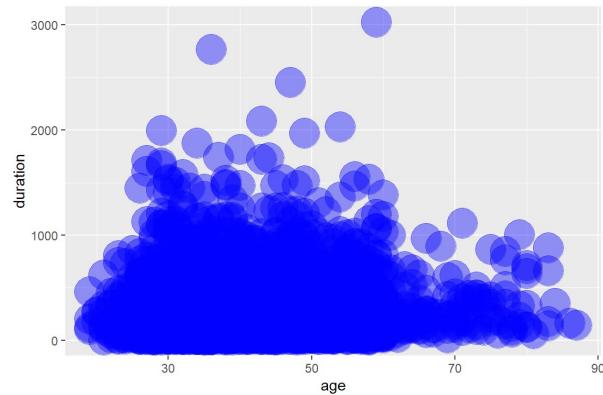
Differentiate groups - group

```
# Use group.
ggplot(bank) +
  geom_point(aes(age, duration, group = contact))
```



Enforce color, put things outside aes

```
## you can also enforce color, put things outside aes
ggplot(bank) +
  geom_point(aes(age, duration), color = "blue", size = 10, alpha = 0.4)
```



What's inside bank's clients? Things to consider

- Which variables in data are categorical?
- Which variables are continuous?
- bio:
 - *age*
 - *job*
 - *marital*
 - *education*
- financial
 - *default*
 - *balance*
 - *housing*
 - *loan*

What's inside bank's clients? Things to consider 2

- communication

- *contact: cellular v.s. telephone v.s. unknown*
- *day/month: maybe good to ignore?*
- *duration:*
- *campaign:*
- *pdays:*
- *pprevious:*
- *poutcome:*

Categorical/Continuous variable

- numeric -> continuous data
- string -> discrete data

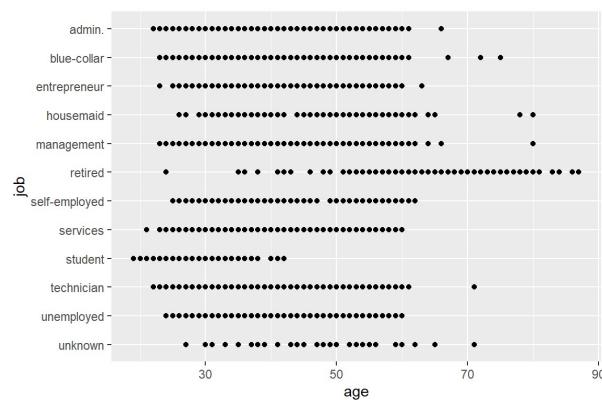
For different type of variables, the scale is also different

- Reverse a categorical (discrete) variable, we use
`scale_y_discrete(limit = rev(levels(...))).`
- Reverse a continuous numerical variable, we use `scale_x_reverse()`.

Exercise

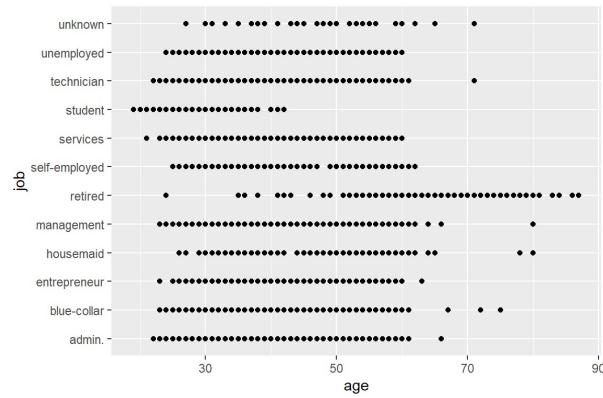
I. What does this figure mean?

```
ggplot(bank, aes(age, job)) +
  geom_point() +
  scale_y_discrete(limit = rev(levels(bank$job)))
```



Exercise

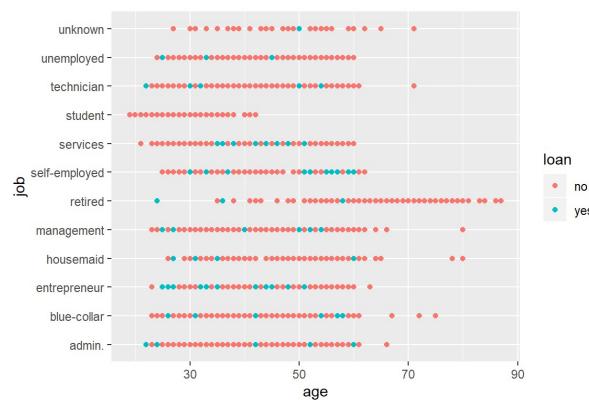
```
# y labels without sort.
ggplot(bank, aes(age, job)) + geom_point()
```



Exercise

2. I tried to plot between job, loan and age. Any better idea?

```
suppressWarnings(
  ggplot(bank, aes(age, job, color = loan)) + geom_point()
)
```



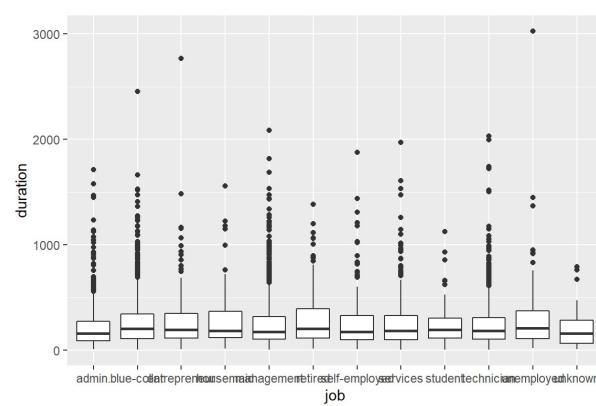
```
## Warning: Using size for a discrete variable is not advised.
```

Other geoms

- `geom_boxplot()`
- `geom_density()`
- `geom_histogram()`
- `geom_bar()`

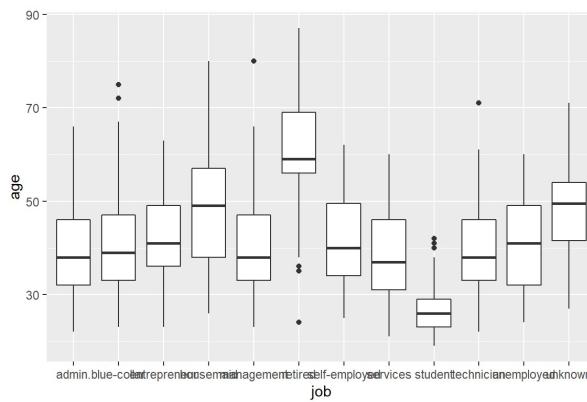
Boxplot: job and duration

```
ggplot(bank, aes(job, duration)) + geom_boxplot()
```



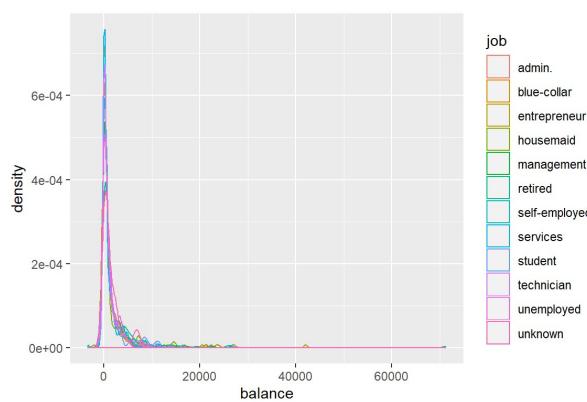
Boxplot: job and age

```
ggplot(bank, aes(job, age)) + geom_boxplot()
```



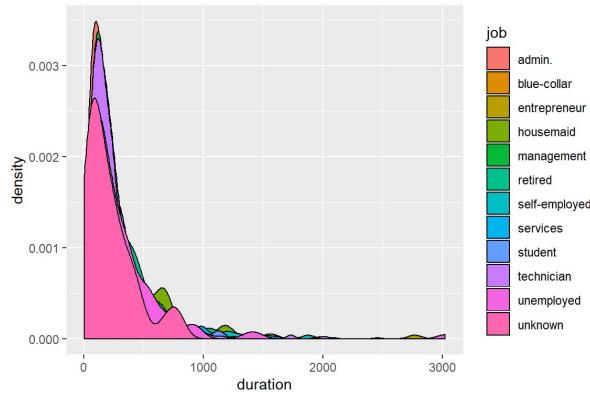
Density: balance and job

```
ggplot(bank, aes(balance, color = job)) + geom_density()
```



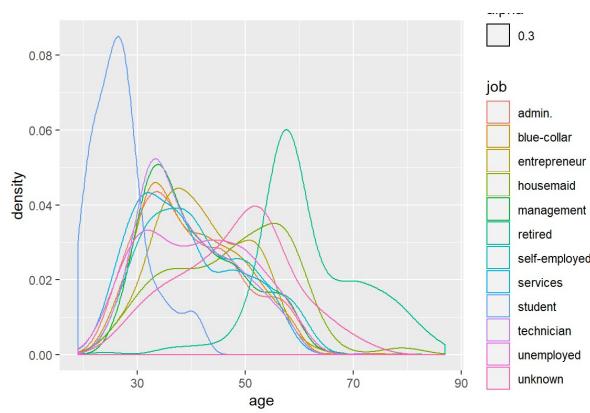
Density: balance and job with fill

```
ggplot(bank, aes(duration, fill = job)) + geom_density()
```



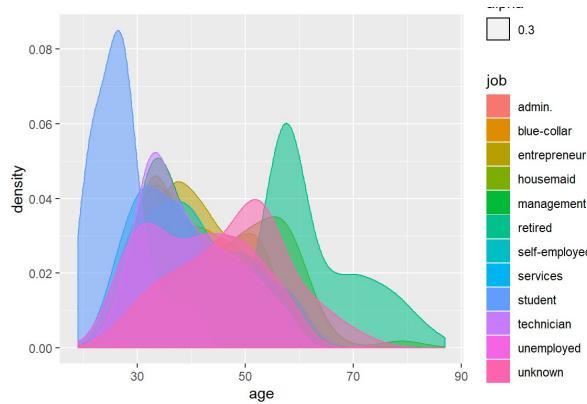
Density: age and job with alpha

```
ggplot(bank, aes(age, color = job, alpha = 0.3)) + geom_density()
```



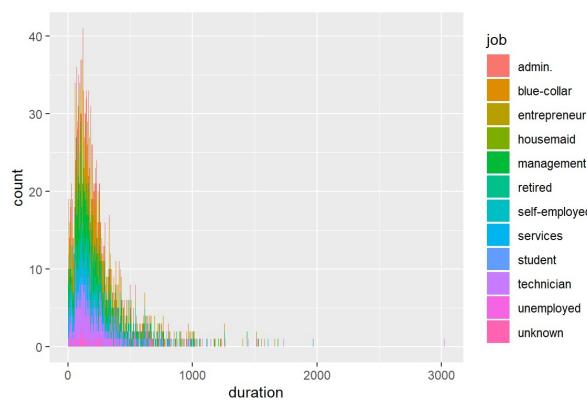
Density: age and job with alpha and fill and color

```
# Which is better?
ggplot(bank, aes(age, color = job, fill = job, alpha = 0.3)) +
  geom_density()
```



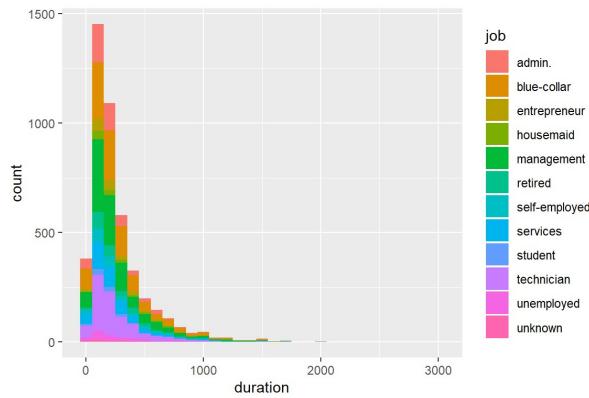
histogram: duration and job and binwidth = 2

```
ggplot(data = bank, mapping = aes(x = duration, fill = job)) +
  geom_histogram(binwidth = 2)
```



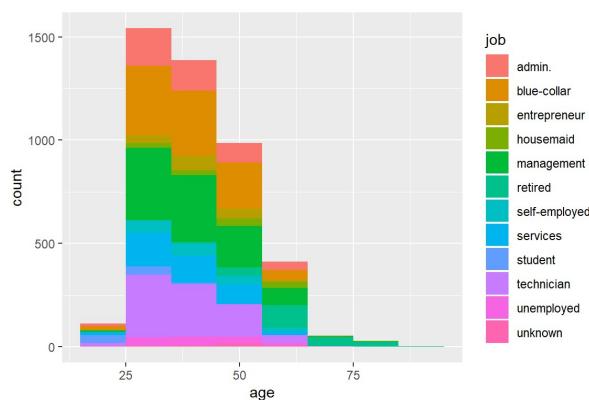
histogram: duration and job and binwidth = 100

```
ggplot(data = bank, mapping = aes(x = duration, fill = job)) +
  geom_histogram(binwidth = 100)
```



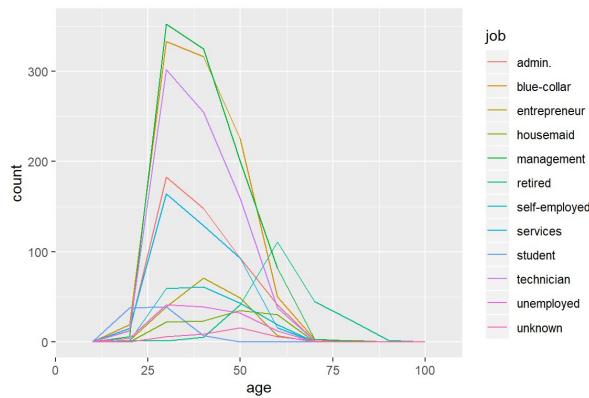
histogram: age and job and fill

```
ggplot(data = bank, mapping = aes(x = age, fill = job)) +
  geom_histogram(binwidth = 10)
```



histogram: age and job and colour

```
ggplot(data = bank, mapping = aes(x = age, colour = job)) +
  geom_freqpoly(binwidth = 10)
```

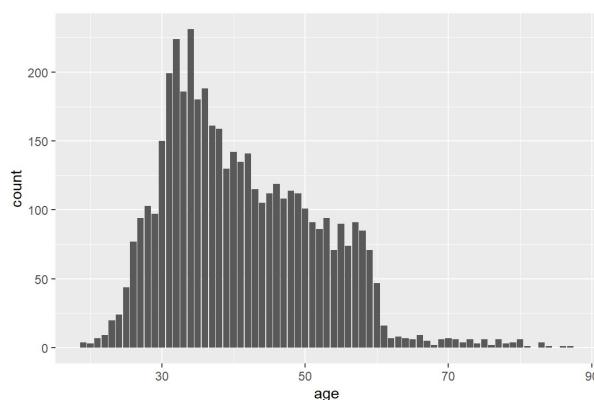


geom_bar

- bar is a statistical function: It counts.

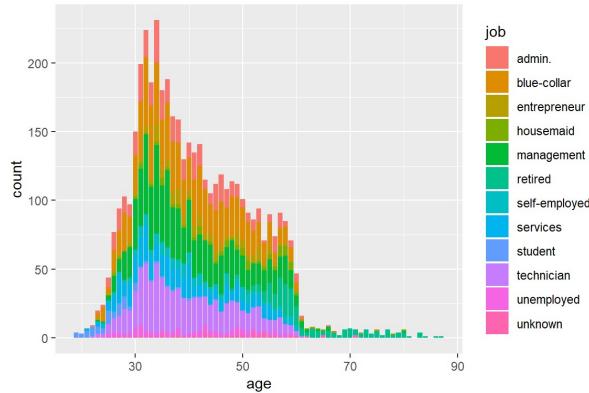
```
# First input parameter to geom_bar is mapping, so we can skip it.
ggplot(bank) + geom_bar(mapping = aes(x = age))
```

```
# We can skip mapping
ggplot(bank) + geom_bar(aes(x = age))
```



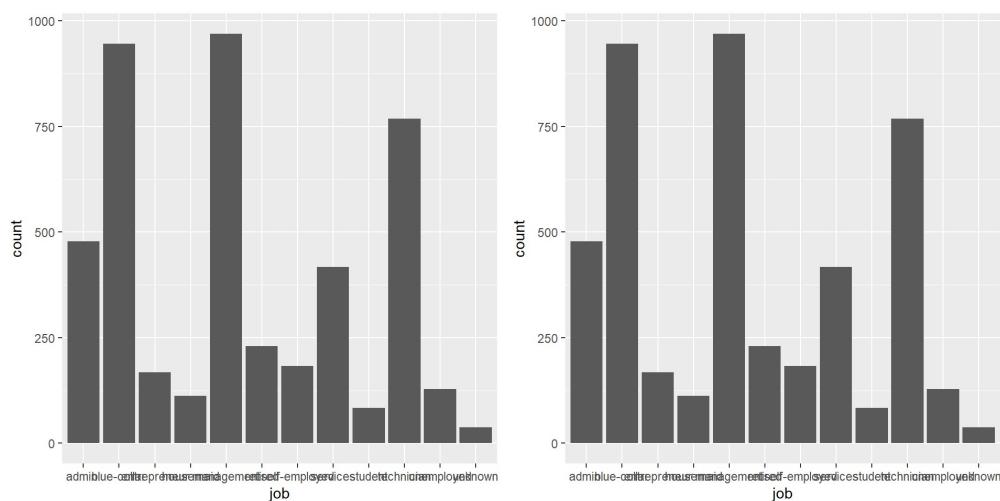
geom_bar with fill: job

```
# comparing to colour, for Bar, we better use fill
# ggplot(data = bank, ) + geom_bar(aes(x = age, colour = job))
ggplot(bank) + geom_bar(mapping = aes(x = age, fill = job))
```



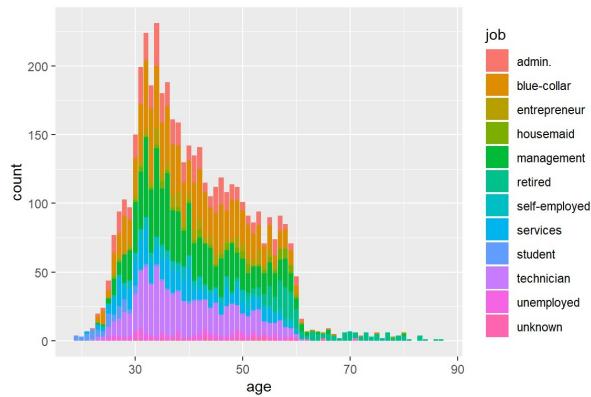
geom_bar with fill: age

```
ggplot(bank) +
  geom_bar(mapping = aes(x = job))
# Color doesn't work, because age is a continuous variable.
ggplot(bank) +
  geom_bar(mapping = aes(x = job, fill = age))
```



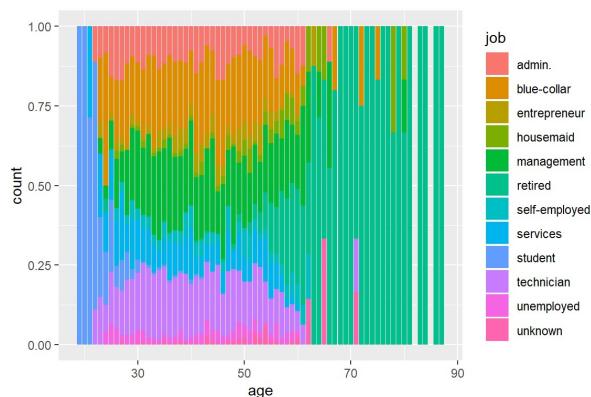
Position for bar

```
ggplot(bank) + geom_bar(mapping = aes(x = age, fill = job))
```



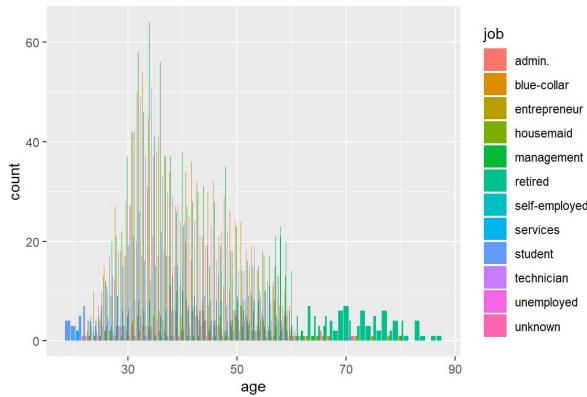
Position for bar: fill

```
# fill to 100%
ggplot(bank) + geom_bar(mapping = aes(x = age, fill = job),
                         position = "fill")
```



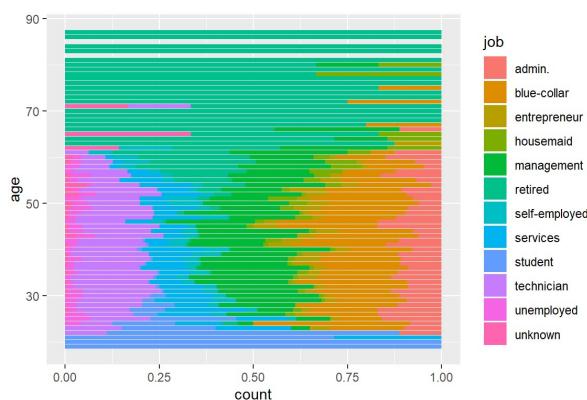
Position for bar: dodge

```
# dodge means "adaptive width of the bar"
ggplot(bank) + geom_bar(mapping = aes(x = age, fill = job),
                        position = "dodge")
```



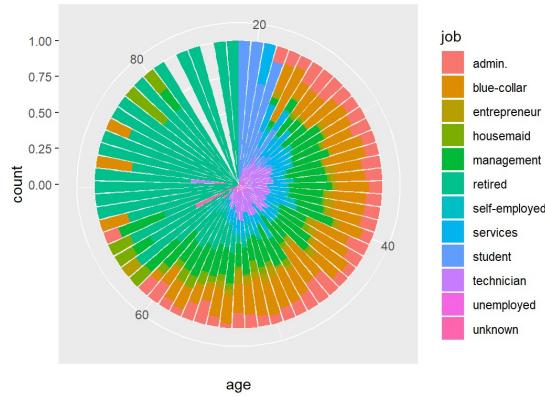
Variations: coord_flip

```
# Switch x and y axis.
# Note any adjustment on x or y axis is effective on the original name.
ggplot(bank) +
  geom_bar(mapping = aes(x = age, fill = job), position = "fill") +
  coord_flip()
```



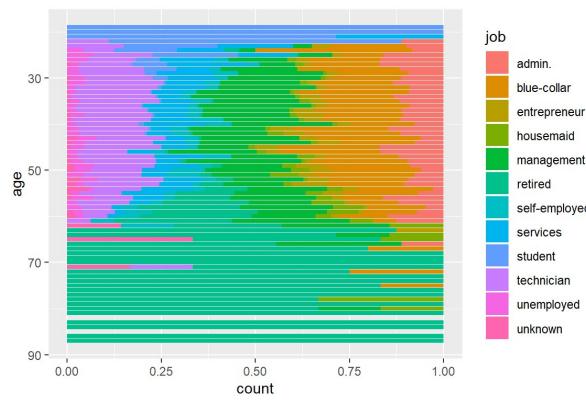
Variations: coord_polar

```
ggplot(bank) +
  geom_bar(mapping = aes(x = age, fill = job), position = "fill") +
  coord_polar()
```



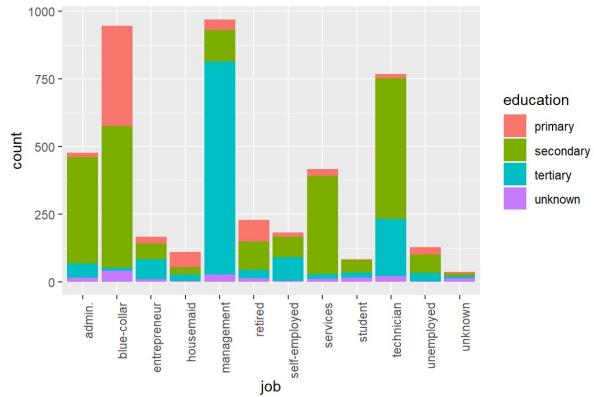
Variations: scale_x_reverse

```
# scale_x_reverse works on continous variable (numeric, date, etc.). Make
      it big to small.
ggplot(bank) +
  geom_bar(mapping = aes(x = age, fill = job), position = "fill") +
  coord_flip() +
  scale_x_reverse()
```



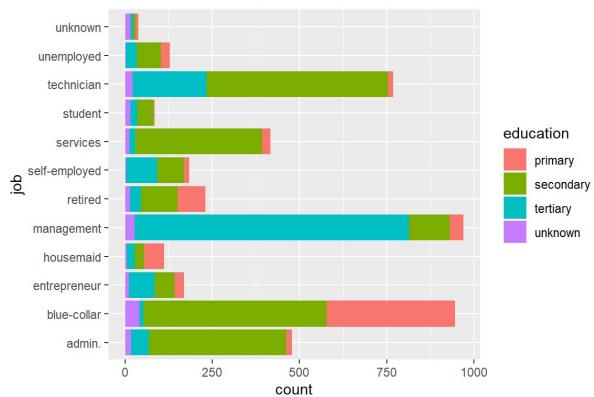
geom_bar: better serves for categorical data

```
ggplot(data = bank, mapping = aes(x = job, fill = education)) +
  geom_bar() +
  theme(axis.text.x = element_text(angle = 90, hjust = 1))
```



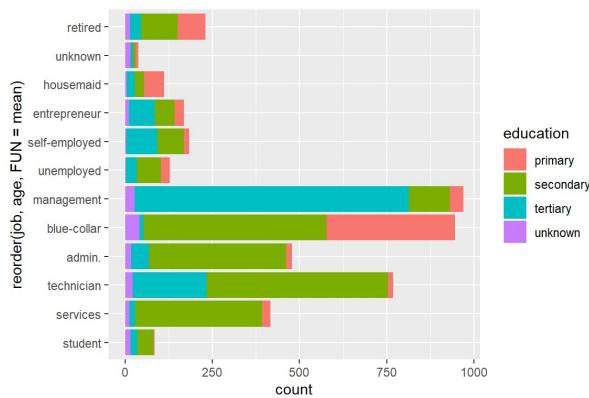
geom_bar: coord_flip

```
ggplot(data = bank, mapping = aes(x = job, fill = education)) +
  geom_bar() + coord_flip()
```



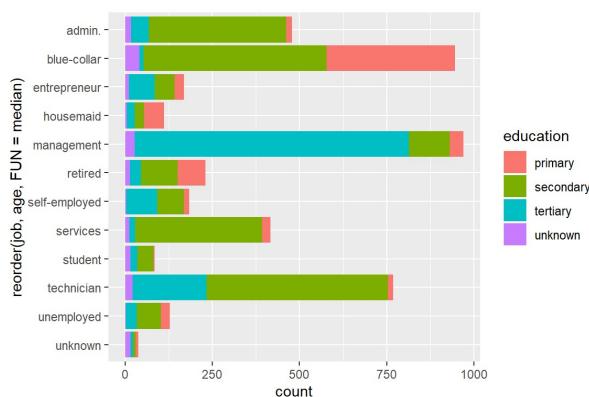
geom_bar: sort job by mean age

```
ggplot(data = bank, mapping = aes(x = reorder(job, age, FUN = mean),
                                    fill = education)) +
  geom_bar() + coord_flip()
```



geom_bar: sort job by alphabetical order

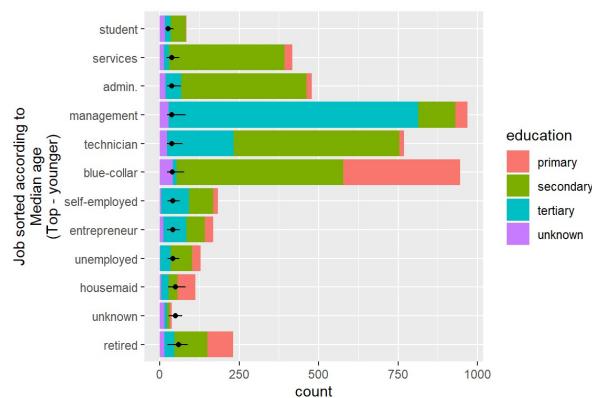
```
# If we want to order job according to alphabetical order.
# use rev(levels(...))
ggplot(data = bank, mapping = aes(x = reorder(job, age, FUN = median),
                                    fill = education)) +
  geom_bar() +
  scale_x_discrete(limit = rev(levels(bank$job))) +
  coord_flip()
```



Bar with composite data

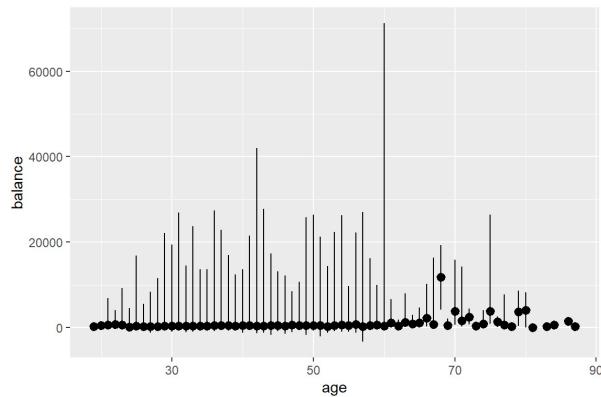
```
ggplot(data = bank, mapping = aes(x = reorder(job, age, FUN = median),
                                    fill = education)) +
  # layer 1
  geom_bar() +
  # If we want to sort the job according to median age
  scale_x_discrete(limit =
    rev(levels(reorder(bank$job, bank$age, FUN = median)))) +
  # And also add age range and median age.
  geom_line(aes(x = job, y = age)) +
  geom_point(data = group_by(bank, job) %>%
    summarize(age = median(age)) %>% ungroup,
             aes(x = job, y = age), inherit.aes = FALSE) +
  xlab("Job sorted according to\nMedian age\n(Top - younger)") +
  coord_flip()
```

Bar with composite data: plot



Data with statistical

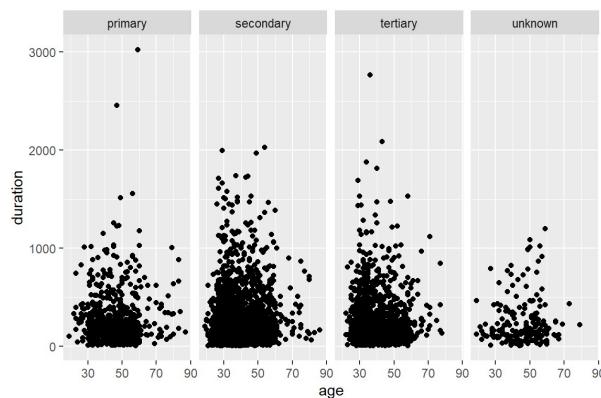
```
ggplot(data = bank) +
  stat_summary(
    mapping = aes(x = age, y = balance),
    fun.ymin = min,
    fun.ymax = max,
    fun.y = median
  )
```



Facets

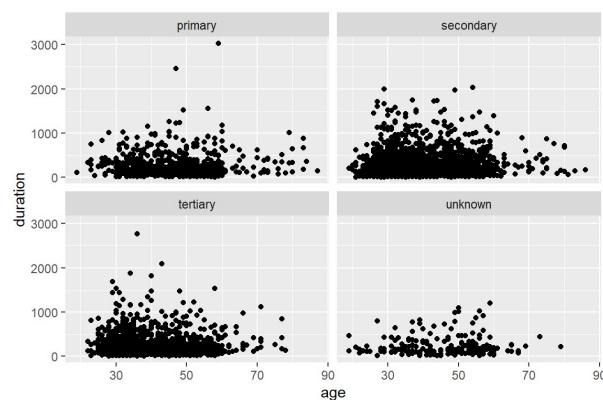
- Create individual figures.
- facet_grid: basic
- facet_wrap: you can control number of rows and cols

```
ggplot(data = bank) +
  geom_point(mapping = aes(x = age, y = duration)) +
  facet_grid(~ education)
```



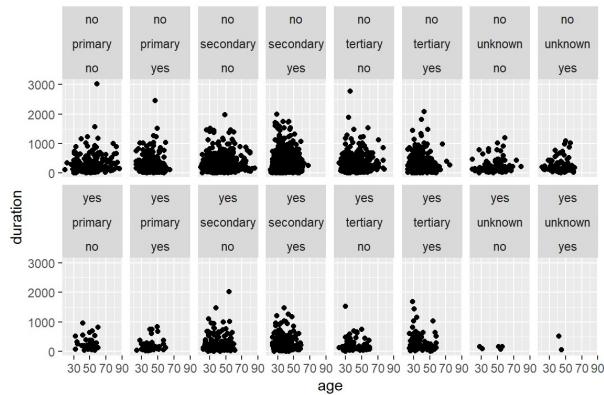
Facets - facet_wrap

```
ggplot(data = bank) +  
  geom_point(mapping = aes(x = age, y = duration)) +  
  facet_wrap(~ education, nrow = 2)
```



Facets - `facet_wrap` multi-dimension

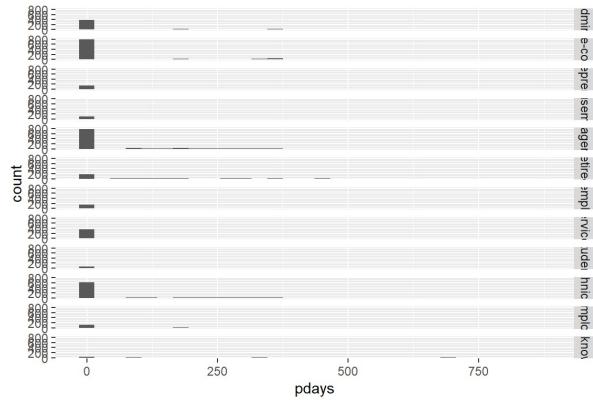
```
ggplot(data = bank) +
  geom_point(mapping = aes(x = age, y = duration)) +
  facet_wrap(loan ~ education ~ housing, nrow = 2)
```



```
# or we can use, facet_grid(loan ~ education ~ housing)
```

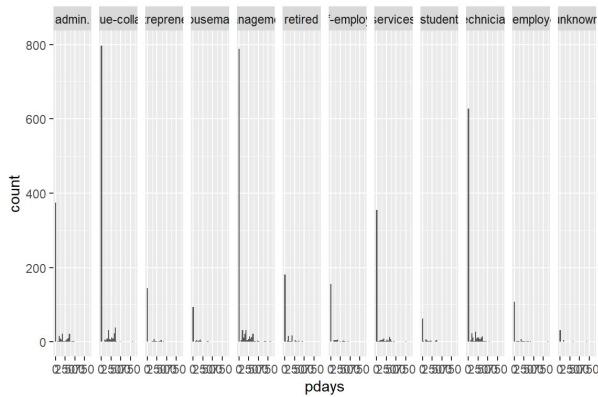
Facets - finding the best

```
# doesn't look great because we have so many jobs.
ggplot(bank, aes(pdays)) + geom_histogram() + facet_grid(job ~ .)
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```



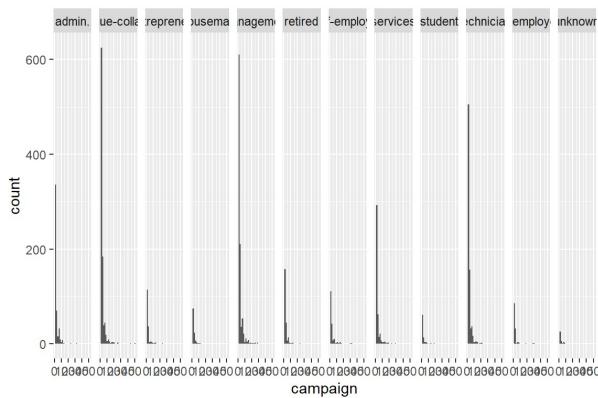
Facets - finding the best. still trying.

```
# Not a good choice, neither
ggplot(bank, aes(pdays)) + geom_histogram() + facet_grid(. ~ job)
## `stat_bin()` `using `bins = 30` . Pick better value with `binwidth` .
```



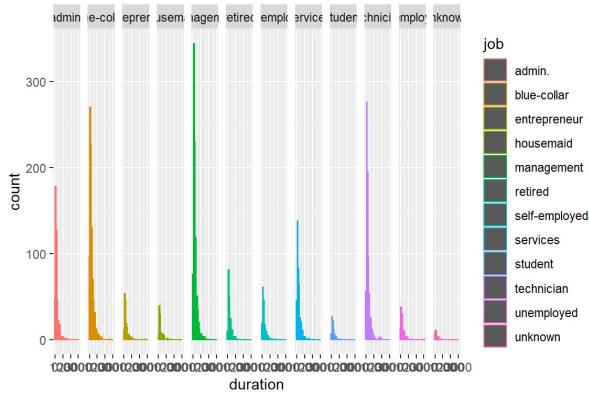
Facets - finding the best. better

```
# Can we do better?
ggplot(bank, aes(campaign)) + geom_histogram() + facet_grid(. ~ job)
## `stat_bin()` `using `bins = 30` . Pick better value with `binwidth` .
```



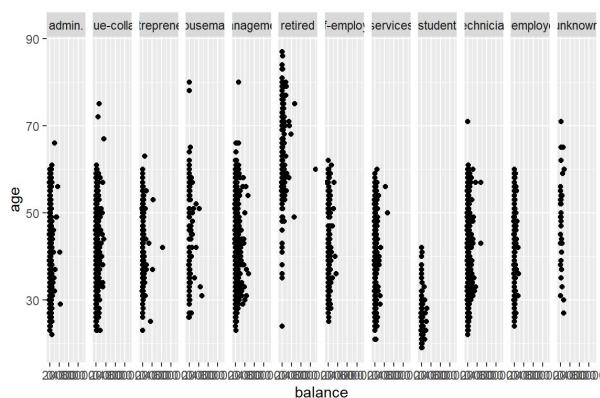
Facets - finding the best. try another

```
ggplot(bank, aes(duration)) + geom_histogram(aes(color = job)) +
  facet_grid(. ~ job)
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```



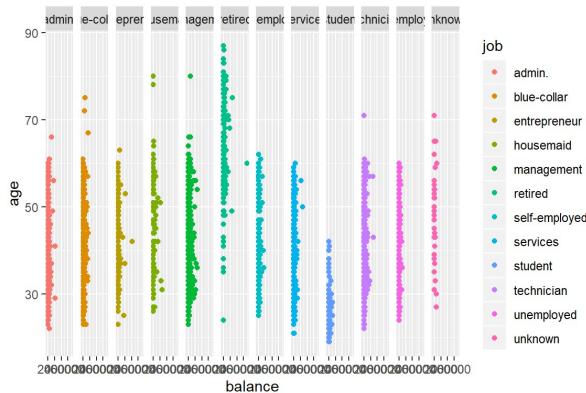
Facets - finding the best. Try points

```
# facet with points is good
ggplot(bank, aes(balance, age)) + geom_point() + facet_grid(. ~ job)
```



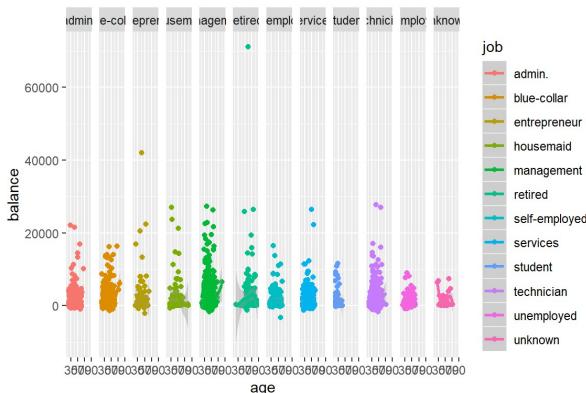
Facets - finding the best. Better with color

```
# do better
ggplot(bank, aes(balance, age)) + geom_point(aes(color = job)) +
  facet_grid(. ~ job)
```



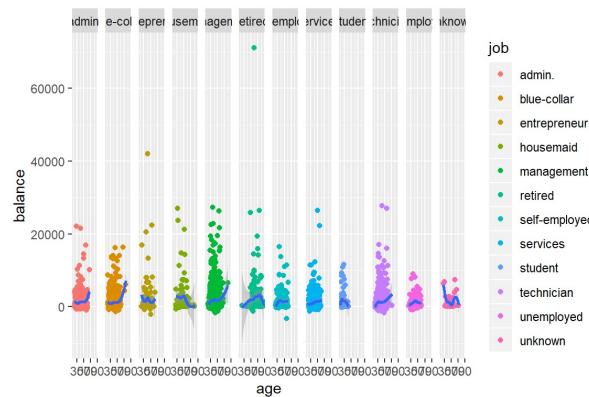
Facets - finding the best. Try Points

```
# Can we apply points between age and balance?
ggplot(bank, aes(age, balance, color = job)) +
  geom_point() + geom_smooth() +
  facet_grid(. ~ job)
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```



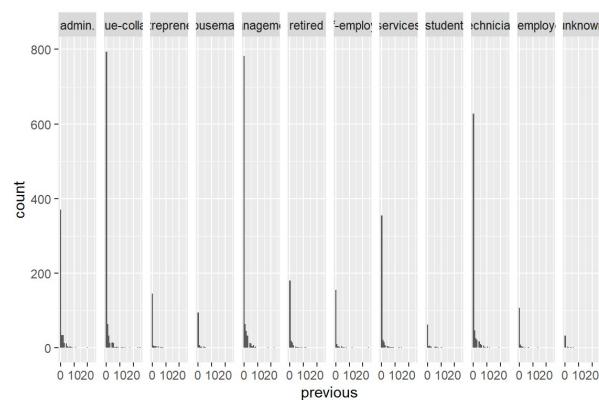
Facets - finding the best. Try Smoothie

```
# Smooth line is mixed with points
ggplot(bank, aes(age, balance)) + geom_point(aes(color = job)) +
  geom_smooth() +
  facet_grid(. ~ job)
## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```



With facets or without facets?

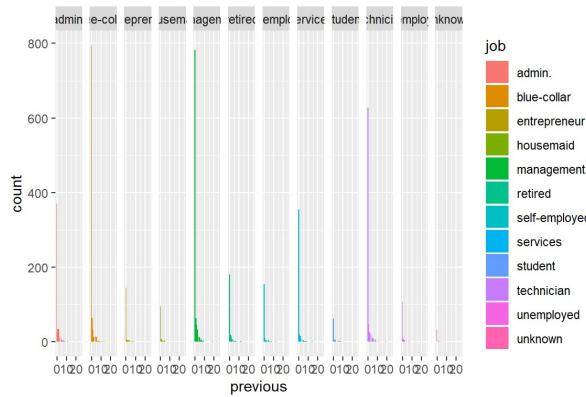
```
ggplot(bank, aes(previous)) + geom_histogram() + facet_grid(. ~ job)
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```



With facets or without facets?

facets with color

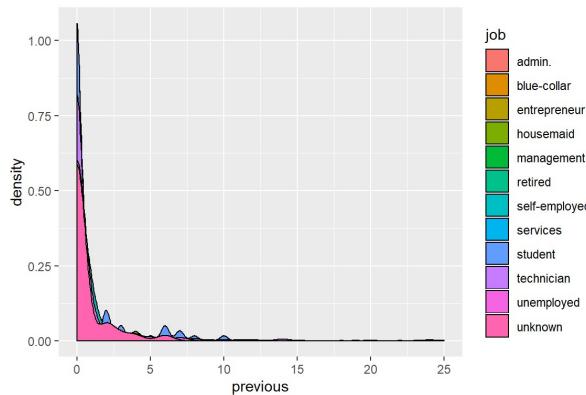
```
ggplot(bank, aes(previous)) + geom_histogram(aes(fill = job)) +
  facet_grid(. ~ job)
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```



With facets or without facets?

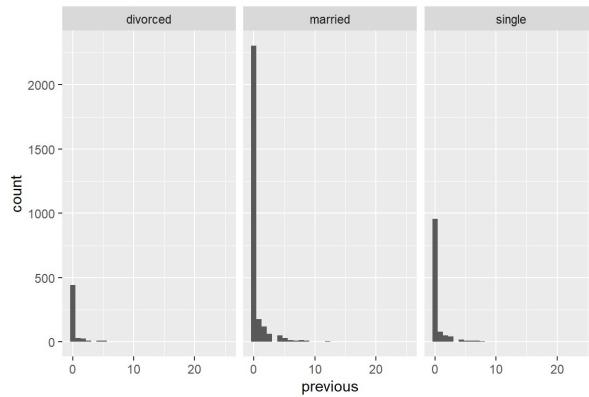
Use density/color on one figure

```
ggplot(bank, aes(previous)) + geom_density(aes(fill = job))
```



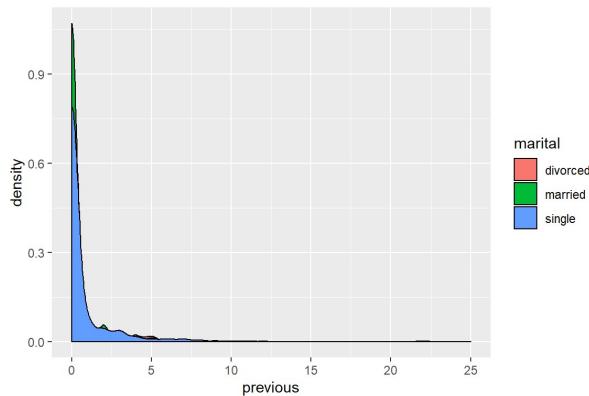
With facets or without facets: Case 2

```
ggplot(bank, aes(previous)) + geom_histogram() +
  facet_grid(. ~ marital)
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```



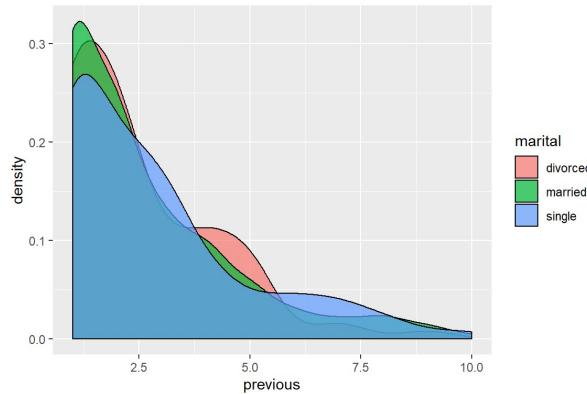
With facets or without facets: geom_density and fill

```
ggplot(bank, aes(previous)) + geom_density(aes(fill = marital))
```



With facets or without facets: xlim

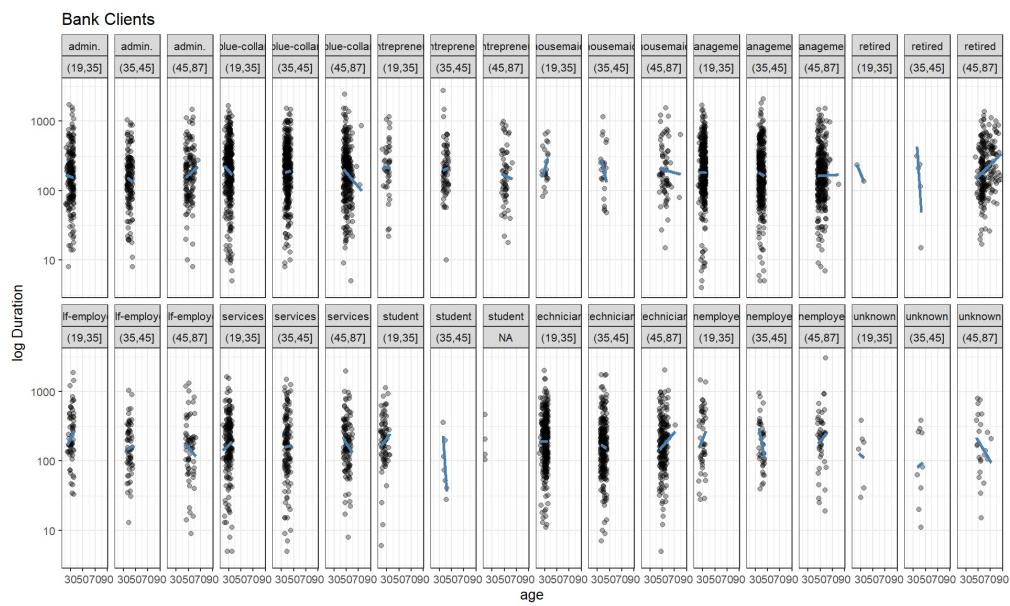
```
ggplot(bank, aes(previous)) +
  geom_density(aes(fill = marital), alpha = 0.7) +
  xlim(1, 10)
## Warning: Removed 3725 rows containing non-finite values (stat_density).
```



Facets in full power

```
# Levels gives more control to the layer and style.
cutpoints <- quantile(bank$age, seq(0, 1, length = 4), na.rm = TRUE)
# The age_group variable is now a categorical factor variable containing
# 3 levels, indicating the ranges of age.
bank$age_group <- cut(bank$age, cutpoints)
levels(bank$age_group)
## [1] "(19,35]" "(35,45]" "(45,87]"
# Use facet_wrap to specify nrow/ncol.
ggplot(bank, aes(age, duration)) +
  geom_point(alpha = 1/3) +
  facet_wrap(job ~ age_group, nrow = 2) +
  geom_smooth(method="lm", se=FALSE, col="steelblue") +
  theme_bw(base_size = 10) +
  labs(x = "age", y = expression("log " * Duration)) +
  scale_y_log10() +
  labs(title = "Bank Clients")
```

Facets in full power: plot



Add theme

default theme is theme_gray()

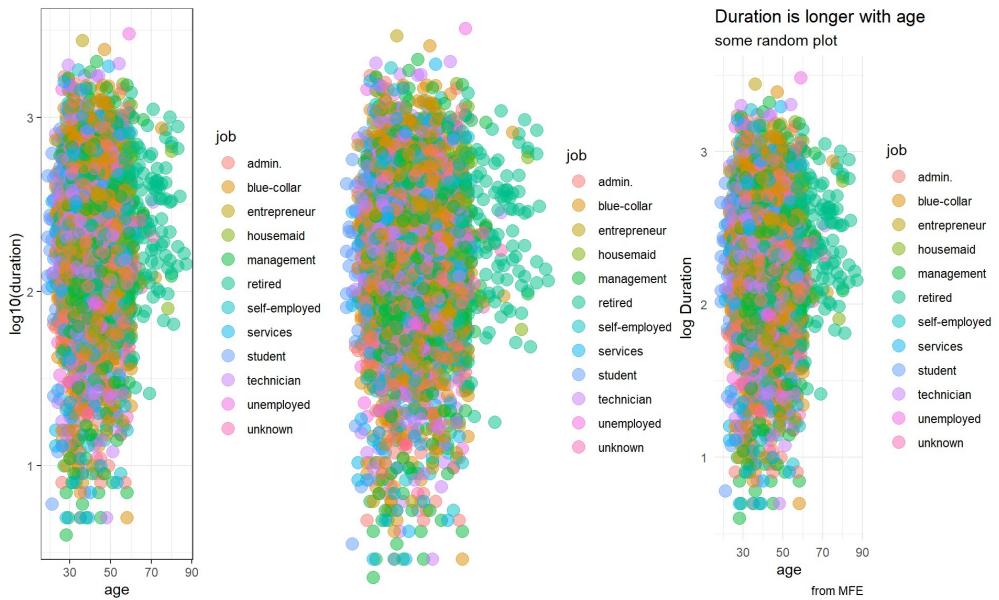
```

g <- ggplot(bank, aes(x = age, y = log10(duration)))
g + geom_point(aes(color = job), size = 4, alpha = 1/2) + theme_bw()
g + geom_point(aes(color = job), size = 4, alpha = 1/2) + theme_void()

g + geom_point(aes(color = job), size = 4, alpha = 1/2) + theme_minimal() +
  labs(title = "Duration is longer with age",
       subtitle = "some random plot",
       caption = "from MFE") +
  labs(x = "age", y = expression("log " * Duration))

```

Add theme: result



ggthemes

- package `ggthemes` provides many other themes.

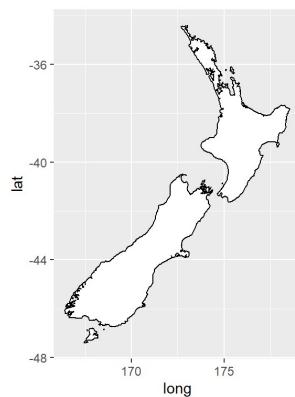
```
library(ggthemes)
## [1] "theme_base" "theme_calc"
## [3] "theme_economist" "theme_economist_white"
## [5] "theme_excel" "theme_few"
## [7] "theme_fivethirtyeight" "theme.foundation"
## [9] "theme_gdocs" "theme_hc"
## [11] "theme_igray" "theme_map"
## [13] "theme_pander" "theme_par"
## [15] "theme_solarized" "theme_solarized_2"
## [17] "theme_solid" "theme_stata"
## [19] "theme_tufte" "theme_wsj"
```

ggplot summary

```
ggplot(data = <DATA>) +
  <GEOM_FUNCTION>(
    mapping = aes(<MAPPINGS>),
    stat = <STAT>,
    position = <POSITION>
  ) +
  <COORDINATE_FUNCTION> +
  <FACET_FUNCTION>
```

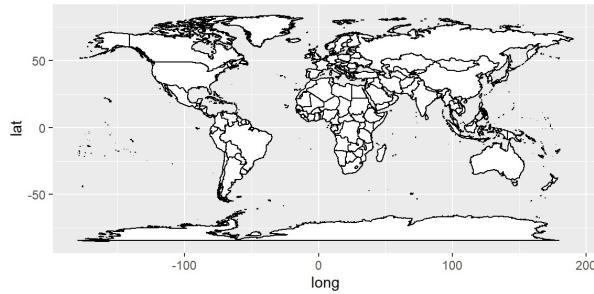
ggplot: one more thing: nz

```
# install.packages("maps")
library(maps)
nz <- map_data("nz")
ggplot(nz, aes(long, lat, group = group)) +
  geom_polygon(fill = "white", colour = "black") +
  coord_quickmap()
```



ggplot: one more thing - world

```
world <- map_data("world")
ggplot(world, aes(long, lat, group = group)) +
  geom_polygon(fill = "white", colour = "black") +
  coord_quickmap()
```



Assignment

- In an R Markdown document (output: html), produce 10 data insights.
 - *Each with a figure and a data story.*
 - *You can re-use about existing examples, up to 5.*

Lecture 9: Shiny/3: Advanced

Review: Display output with `render*` () functions

- `render*` () arguments are code used to build and rebuild object
- `render*` () function re-runs the code with every change in the input

Review: render/output pair

- Static table from df, mat, etc.s
 - `renderTable()/tableOutput()`
- Interactive table from data frame, matrix or other table-like structure
 - `renderDataTable()/dataTableOutput()`
- Plot
 - `renderPlot()/plotOutput()`
- Get continuous output
 - `renderPrint()/verbatimTextOutput() or textOutput()`
- Get last result
 - `renderText()/verbatimTextOutput() or textOutput()`
- Customized UI elements
 - `uiOutput()/renderUI()`

Review: render*

- Allow binding of one output to multiple inputs

```
output$hist <- renderPlot({
  hist(data())
})

output$stat <- renderPlot({
  summary(data())
})
```

Review: observeEvent

- Allow binding of multiple outputs to multiple inputs.
- Use of `isolate` to peek the value not to react to its change every time.

```
ActionButton(inputId = "go", label = "Click me")

observeEvent(input$go, {
  # Use of isolate to *peek* the value not to react to it.
  num_input <- isolate(input$num_input)

  output$plot1 <- renderPlot({
    # if we use input$num_input here, we build a direct reactive link
    # between output$plot1 and input$num_input. This is not what we designed.
    plot(1:number_input, runif(num_input))
  })

  output$table1 <- renderTable({ ... })
})
```

Review: When code gets to run.

- `ui`: client. run once per user per session.
- `server`: run once per session
- code inside a reactive function runs with every input change.

Advanced Shiny

- **Input:** `update***Input` functions (You can update output with new content.)
- Dynamic UI to create inputs and outputs dynamically.
- Graphics output: `gridExtra`
- Table output: `kableExtra`

update***Input

- Update various input values
 - `updateSelectionInput(...)`
 - `updateNumericInput(...)`

```
# shiny-36-update.R

library(shiny)

ui <- fluidPage(
  numericInput("shock", "Shock", value = round(runif(1) * 1000), 0),
  actionButton("add", "Add"),
  checkboxGroupInput("scenarios", "Scenarios", choices = c(), selected = c()),

  verbatimTextOutput("o1")
)

scenarios <- c(-100, -50, 0, 50, 100)

server <- function(input, output, session) {
  updateCheckboxGroupInput(session, "scenarios",
    choices = scenarios,
    selected = scenarios)

  observeEvent(input$add, {
    shock <- isolate(input$shock)

    if (!(shock %in% scenarios)) {
      scenarios <- sort(c(scenarios, shock))
      updateCheckboxGroupInput(session, "scenarios",
        choices = scenarios,
        selected = scenarios)
    }
  })
}
```

```
        selected = scenarios
    }
    # put a new random value
    updateNumericInput(session, "shock", value = round(runif(1) * 1000))
  })

output$ol <- renderPrint({
  x <- input$scenarios
  str(x)
  cat(paste0("length: ", length(x), "\n"))
  cat(paste0(x, "\n"))
})
}

shinyApp(ui, server)
```

renderUI

- Dynamically creation of UI (user interface) with input and outputs.
- Append new items to tagList()

Create dynamic output tagList()

```
# shiny-34-renderUI.R

library(shiny)

ui <- fluidPage(
  uiOutput("p1")
)

server <- function(input, output, session) {
  output$p1 <- renderUI({
    uiopt <- tagList()

    for (i in 1:3) {
      uiopt <- tagList(
        uiopt,
        h1(paste0("HTML t", i)),
        h1(paste0("Plot p", i)),
        plotOutput(paste0("plot", i)))
    }

    uiopt
  })

  output[[paste0("plot", 1)]] <- renderPlot({ hist(rnorm(1000, 0, 1)) })
  output$plot2 <- renderPlot({ hist(runif(1000)) })

  for (i in 1:3) {
    output[[paste0("plot", i)]] <- renderPlot({ hist(rnorm(1000, 0, i)) })
  }
}

shinyApp(ui, server)
```

Create dynamic output 2

You can use newly created UI immediately

```
# shiny-35-renderUI-2.R

library(shiny)

ui <- fluidPage(
  uiOutput("p1")
)

server <- function(input, output, session) {
  output$p1 <- renderUI({
    t1 <- tagList(
      h1("HTML t1"),
      uiOutput("t1"),
      h1("Plot p1p1"),
      plotOutput("p1p1")
    )
  })

  t1
})

output$t1 <- renderUI({
  tagList(
    h1("HTML p1t1 inside t1"),
    plotOutput("p1t1")
  )
})

output$p1t1 <- renderPlot({
  # hist(runif(1000))
  plot(1:100, runif(100))
})
```

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```
  output$p1p1 <- renderPlot({
    plot(1:100, runif(100))
  })

}

shinyApp(ui, server)
```

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Create dynamic output 3

```
# shiny-32-renderUI.R

library(shiny)
library(knitr)
library(kableExtra)

ui <- fluidPage(
  numericInput("num", "Num", 3),
  uiOutput("p1"),
  hr(),
  tableOutput("p2")
)

server <- function(input, output, session) {
  observe({
    row_num <- input$num

    output$p1 <- renderUI({
      tagList(
        tags$h1("This is a header"),
        {
          if (row_num > 0 & row_num < 7) {
            hx <- paste0("h", row_num)
            (tags[[hx]])(toupper(hx))
          } else {
            (tags[["h6"]])(toupper("h6"))
          }
        },
        numericInput("num_plot", "Give a number",
                    value = round(runif(1, min = 0, max = nrow(iris)), 0),
                    min = 0, max = nrow(iris)),
        plotOutput("plot"),

        tags$h3("kable can't be used with tagList."),
        kable(iris[1:row_num, , drop = T], format = "html")
      )
    })
  })
}

# num_plot is the newly created input.
# plot is the newly created output.
# You can use the newly created input/output immediately
# This is particularly useful for creating multiple plots and tables.
output$plot <- renderPlot({
  if (input$num_plot > 0) {
    ggplot(iris[1:input$num_plot, , drop = F],
           aes(x = Sepal.Length, y = Petal.Width)) +
      geom_point() +
      geom_smooth() +
      theme_minimal()
  }
})

# Use anything together with kable, use function() { paste0(...) }
output$p2 <- function() {
  paste0(
    tags$h1("kable is used inside a function()"),
    kable(iris[1:row_num, , drop = T], format = "html"))
}

shinyApp(ui, server)
```

```
)
})

# num_plot is the newly created input.
# plot is the newly created output.
# You can use the newly created input/output immediately
# This is particularly useful for creating multiple plots and tables.
output$plot <- renderPlot({
  if (input$num_plot > 0) {
    ggplot(iris[1:input$num_plot, , drop = F],
           aes(x = Sepal.Length, y = Petal.Width)) +
      geom_point() +
      geom_smooth() +
      theme_minimal()
  }
})

# Use anything together with kable, use function() { paste0(...) }
output$p2 <- function() {
  paste0(
    tags$h1("kable is used inside a function()"),
    kable(iris[1:row_num, , drop = T], format = "html"))
}

shinyApp(ui, server)
```

Dynamic input and update***Input

- Update various input values

- `updateSelectionInput(...)`
- `updateNumericInput(...)`

```
# shiny-36-update.R

library(shiny)

ui <- fluidPage(
  numericInput("shock", "Shock", value = round(runif(1) * 1000), 0),
  actionButton("add", "Add"),
  checkboxGroupInput("scenarios", "Scenarios", choices = c(), selected = c()),
  verbatimTextOutput("o1")
)

scenarios <- c(-100, -50, 0, 50, 100)

server <- function(input, output, session) {
  updateCheckboxGroupInput(session, "scenarios",
    choices = scenarios,
    selected = scenarios)

  observeEvent(input$add, {
    shock <- isolate(input$shock)

    if (!(shock %in% scenarios)) {
      scenarios <- sort(c(scenarios, shock))
      updateCheckboxGroupInput(session, "scenarios",
        choices = scenarios,
        selected = scenarios)
    }
  })
}

output$o1 <- renderPrint({
  x <- input$scenarios
  str(x)
  cat(paste0("length: ", length(x), "\n"))
  cat(paste0(x, "\n"))
})

shinyApp(ui, server)
```

```
  selected = scenarios)
}

# put a new random value
updateNumericInput(session, "shock", value = round(runif(1) * 1000))
})

output$o1 <- renderPrint({
  x <- input$scenarios
  str(x)
  cat(paste0("length: ", length(x), "\n"))
  cat(paste0(x, "\n"))
})

shinyApp(ui, server)
```

Very dynamic

```
# shiny-37-createDynamic.R

library(shiny)

ui <- fluidPage(
  uiOutput("p1"),
  verbatimTextOutput("o1")
)

scenarios <- c(-100, -50, 0, 50, 100)

server <- function(input, output, session) {
  baseList <- tagList(
    numericInput("shock", "Shock", value = round(runif(1) * 1000), 0),
    actionButton("add", "Add")
  )

  gen_ui <- function(scenarios, values = NA) {
    output$p1 <- renderUI({
      tl <- baseList
      # print(scenarios)
      for (ss in 1:length(scenarios)) {
        nm <- paste0("scenarios_", ss)
        if (is.na(values[ss])) {
          val <- TRUE
        } else {
          val <- values[ss]
        }
        tl <- tagList(tl, checkboxInput(nm, scenarios[ss], value = val))
        # print(paste0("scenarios_", ss, ", ", scenarios[ss], "\n"))
      }
      tl
    })
  }
}
```

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```
gen_ui(scenarios)

observeEvent(input$add, {
  shock <- isolate(input$shock)
  if (!(shock %in% scenarios)) {
    vals <- purrr::map_lgl(1:length(scenarios),
                           function(ss) {
                             isolate(input[[paste0("scenarios_", ss)]])
                           })
    scenarios <- c(scenarios, shock)
    gen_ui(scenarios, vals)
  }

  # put a new random value
  updateNumericInput(session, "shock", value = round(runif(1) * 1000))
})

output$o1 <- renderPrint({
  print(names(input))
  print(isolate(input[["scenarios_1"]]))
  x <- purrr::keep(1:length(scenarios),
                  function(ss) {
                    isolate(input[[paste0("scenarios_", ss)]])
                  })
  x <- scenarios[x]
  str(x)
  cat(paste0("length: ", length(x), "\n"))
  cat(paste0(x, "\n"))
})
}

shinyApp(ui, server)
```

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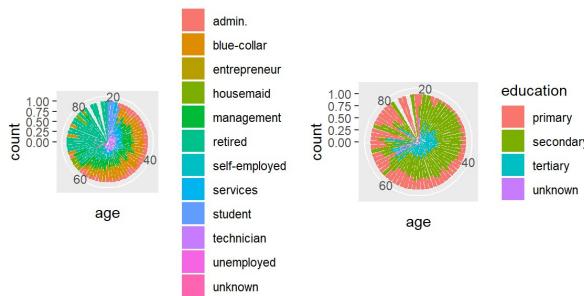
ggplot/gridExtra

If we need to generate multiple plots. ggplot has a companion package to arrange plots.

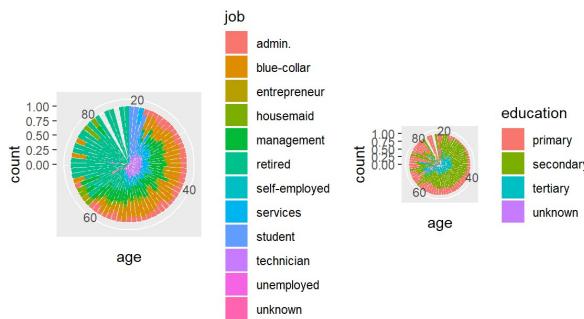
SxS: side by side

```
library(gridExtra)
p1 <- ggplot(bank) + geom_bar(mapping = aes(x = age, fill = job),
                                 position = "fill") + coord_polar()
p2 <- ggplot(bank) + geom_bar(mapping = aes(x = age, fill = education),
                                 position = "fill") + coord_polar()
```

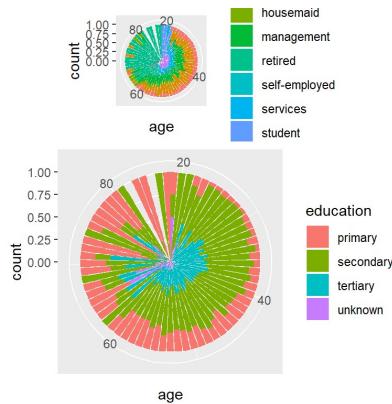
```
grid.arrange(p1, p2, ncol=2, nrow=1)
```



```
grid.arrange(p1, p2, ncol=2, nrow=1, widths = c(4,3))
```



```
grid.arrange(p1, p2, ncol=1, nrow=2, heights = c(2,4))
```



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ggplot/gridExtra

```
library(tibble)
library(ggplot2)
library(gridExtra)

df <- tibble(x = rnorm(1000), y = rnorm(1000))

hist_top <- ggplot(df, aes(x = x)) + geom_density()

empty <-
  ggplot() + geom_point(aes(1,1), colour="white") +
  theme(axis.ticks=element_blank(),
        panel.background=element_blank(),
        axis.text.x=element_blank(), axis.text.y=element_blank(),
        axis.title.x=element_blank(), axis.title.y=element_blank())

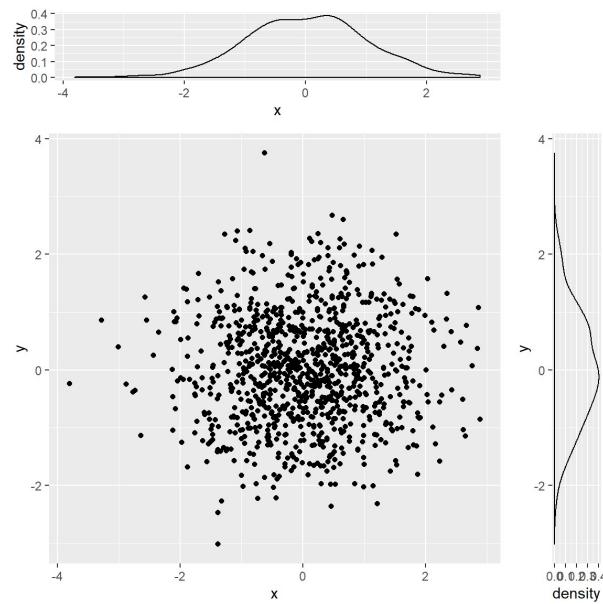
scatter <- ggplot(df, aes(x = x, y = y)) + geom_point()

hist_right <- ggplot(df, aes(x = y)) + geom_density() + coord_flip()

grid.arrange(hist_top, empty, scatter, hist_right,
            ncol=2, nrow=2,
            widths=c(3.5, 0.7), heights=c(1, 4))
```

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ggplot/gridExtra: result



knitr/kableExtra

kable is provided by knitr package. kableExtra enhance it with more functions.
So we load both packages.

```
```{r shiny_block}
library(knitr)
library(kableExtra)

This is HTML output
kable(df, format = "html")

Use function() { } to output html
output$p1 <- function() {
 kable(df, format = "html")
}
```

```

kable_styling

- Get all styles from here https://cran.r-project.org/web/packages/kableExtra/vignettes/awesome_table_in_html.html
- style

```
mtcars[1:10, , drop = F] %>%
  kable("html") %>%
    kable_styling(bootstrap_options = c("striped", "hover", "condensed"),
                  font_size = 12,
                  full_width = F, # True for left-to-right width
                  position = "left") # if full_width == F
```

| | mpg | cyl | disp | hp | drat | wt | qsec | vs | am | gear | carb |
|-------------------|------|-----|-------|-----|------|-------|-------|----|----|------|------|
| Mazda RX4 | 21.0 | 6 | 160.0 | 110 | 3.90 | 2.620 | 16.46 | 0 | 1 | 4 | 4 |
| Mazda RX4 Wag | 21.0 | 6 | 160.0 | 110 | 3.90 | 2.875 | 17.02 | 0 | 1 | 4 | 4 |
| Datsun 710 | 22.8 | 4 | 108.0 | 93 | 3.85 | 2.320 | 18.61 | 1 | 1 | 4 | 1 |
| Hornet 4 Drive | 21.4 | 6 | 258.0 | 110 | 3.08 | 3.215 | 19.44 | 1 | 0 | 3 | 1 |
| Hornet Sportabout | 18.7 | 8 | 360.0 | 175 | 3.15 | 3.440 | 17.02 | 0 | 0 | 3 | 2 |
| Valiant | 18.1 | 6 | 225.0 | 105 | 2.76 | 3.460 | 20.22 | 1 | 0 | 3 | 1 |
| Duster 360 | 14.3 | 8 | 360.0 | 245 | 3.21 | 3.570 | 15.84 | 0 | 0 | 3 | 4 |

| | mpg | cyl | disp | hp | drat | wt | qsec | vs | am | gear | carb |
|-----------|------|-----|-------|-----|------|-------|-------|----|----|------|------|
| Merc 240D | 24.4 | 4 | 146.7 | 62 | 3.69 | 3.190 | 20.00 | 1 | 0 | 4 | 2 |
| Merc 230 | 22.8 | 4 | 140.8 | 95 | 3.92 | 3.150 | 22.90 | 1 | 0 | 4 | 2 |
| Merc 280 | 19.2 | 6 | 167.6 | 123 | 3.92 | 3.440 | 18.30 | 1 | 0 | 4 | 4 |

kable_styling: column_spec

```
mtcars[1:10, , drop = F] %>%
  kable("html") %>%
    kable_styling(bootstrap_options = c("striped", "hover", "condensed"),
                  font_size = 12,
                  full_width = F, # True for left-to-right width
                  position = "left") %>% # if full_width == FALSE
    column_spec(1, bold = T, border_right = TRUE) %>%
    column_spec(2, width = "30em", background = "yellow")
```

| | mpg cyl disp hp drat wt qsec vs am gear carb |
|-------------------|--|
| Mazda RX4 | 21.0 6 160.0 110 3.90 2.620 16.46 0 I 4 4 |
| Mazda RX4 Wag | 21.0 6 160.0 110 3.90 2.875 17.02 0 I 4 4 |
| Datsun 710 | 22.8 4 108.0 93 3.85 2.320 18.61 I I 4 I |
| Hornet 4 Drive | 21.4 6 258.0 110 3.08 3.215 19.44 I 0 3 I |
| Hornet Sportabout | 18.7 8 360.0 175 3.15 3.440 17.02 0 0 3 2 |
| Valiant | 18.1 6 225.0 105 2.76 3.460 20.22 I 0 3 I |
| Duster 360 | 14.3 8 360.0 245 3.21 3.570 15.84 0 0 3 4 |
| Merc 240D | 24.4 4 146.7 62 3.69 3.190 20.00 I 0 4 2 |
| Merc 230 | 22.8 4 140.8 95 3.92 3.150 22.90 I 0 4 2 |
| Merc 280 | 19.2 6 167.6 123 3.92 3.440 18.30 I 0 4 4 |

kable_styling: row_spec

```
mtcars[1:10, , drop = F] %>%
  kable("html") %>%
    kable_styling(bootstrap_options = c("striped", "hover", "condensed"),
                  font_size = 12,
                  full_width = F, # True for left-to-right width
                  position = "left") %>% # if full_width == F
    column_spec(5:7, bold = TRUE) %>%
    row_spec(3:5, bold = T, color = "white", background = "#D7261E")
```

| | mpg | cyl | disp | hp | drat | wt | qsec | vs | am | gear | carb |
|-------------------|------|-----|-------|-----|------|-------|-------|----|----|------|------|
| Mazda RX4 | 21.0 | 6 | 160.0 | 110 | 3.90 | 2.620 | 16.46 | 0 | 1 | 4 | 4 |
| Mazda RX4 Wag | 21.0 | 6 | 160.0 | 110 | 3.90 | 2.875 | 17.02 | 0 | 1 | 4 | 4 |
| Datsun 710 | 22.8 | 4 | 108.0 | 93 | 3.85 | 2.320 | 18.61 | 1 | 1 | 4 | 1 |
| Hornet 4 Drive | 21.4 | 6 | 258.0 | 110 | 3.08 | 3.215 | 19.44 | 1 | 0 | 3 | 1 |
| Hornet Sportabout | 18.7 | 8 | 360.0 | 175 | 3.15 | 3.440 | 17.02 | 0 | 0 | 3 | 2 |
| Valiant | 18.1 | 6 | 225.0 | 105 | 2.76 | 3.460 | 20.22 | 1 | 0 | 3 | 1 |
| Duster 360 | 14.3 | 8 | 360.0 | 245 | 3.21 | 3.570 | 15.84 | 0 | 0 | 3 | 4 |
| Merc 240D | 24.4 | 4 | 146.7 | 62 | 3.69 | 3.190 | 20.00 | 1 | 0 | 4 | 2 |
| Merc 230 | 22.8 | 4 | 140.8 | 95 | 3.92 | 3.150 | 22.90 | 1 | 0 | 4 | 2 |
| Merc 280 | 19.2 | 6 | 167.6 | 123 | 3.92 | 3.440 | 18.30 | 1 | 0 | 4 | 4 |

kable_styling: cell_spec



```
vol_surface <- tibble(tenor = c("1M", "2M", "3M", "6M"),
`0.1` = c(0.472, 0.435, 0.391, 0.29),
`0.25` = c(0.431, 0.41, 0.337, 0.28),
`0.5` = c(0.398, 0.30, 0.251, 0.2),
`0.75` = c(0.428, 0.336, 0.307, 0.249),
`0.9` = c(0.457, 0.411, 0.391, 0.278))

# Coloring for volatility surface:
# Include all cells for colors, using gather, cell_spec, then spread
library(knitr)
library(kableExtra)
gather(vol_surface, key = "delta", value = "vol", -tenor) %>%
# cell_spec takes column vol. spec_color also takes column vol values into
# consideration.
# We take half of the spectrum - yellow to red.
# Color spectrum: "magma" (or "A"), "inferno" (or "B"),
# "plasma" (or "C"), and "viridis" (or "D", the default option).
```

```
mutate(vol = cell_spec(
  vol, "html", color = "black", bold = T,
  background = spec_color(vol, begin = 0.5, end = 1,
                           option = "A", direction = -1))) %>%
spread(key = "delta", value = "vol") %>%
kable("html", escape = F, align = "c") %>%
kable_styling("striped", full_width = FALSE)
```

| tenor | 0.1 | 0.25 | 0.5 | 0.75 | 0.9 |
|-------|-------|-------|-------|-------|-------|
| 1M | 0.472 | 0.431 | 0.398 | 0.428 | 0.457 |
| 2M | 0.435 | 0.41 | 0.3 | 0.336 | 0.411 |
| 3M | 0.391 | 0.337 | 0.251 | 0.307 | 0.391 |
| 6M | 0.29 | 0.28 | 0.2 | 0.249 | 0.278 |