FE8828 Programming Web Applications in Finance

Week 1: 0. Introduction 1. What's Internet? What's Web? 2. Launch into the Cloud 3. R Markdown and R Shiny/1: layout 4. R Programming/1

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Section 1

0. Introduction to FE8828

Introduction

- With FE8828, I hope to bridge the theory and practice.
- Often, when we study, teachers feed us many theories. We learnt the “result” (and forgot most of them) but not the “process”.
- We learn about the “process” in this course.
- The “process” leads us to think how to apply theory, how theory work and how it doesn’t work. And better memory of the theory.
- Because finance is an empirical science. All theories come from observation and need to be validated by the real world.

Finance: a workflow point of view

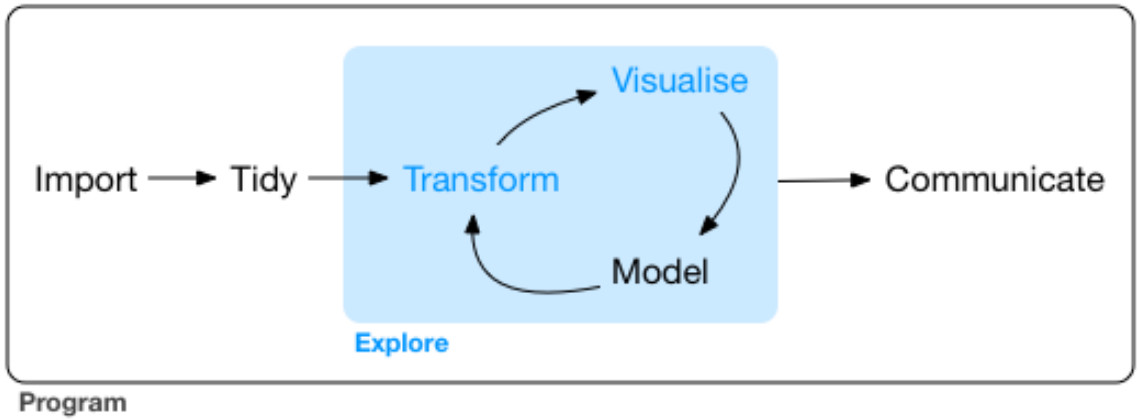
- We go through such process with finance applications.

  Data -> (Model <-> Appplication) -> Result

- Application is usually composed of
  - Input
  - Computing Engine for Valuation/Risk/Trading
  - Output
- Result is
  - Value
  - Risk
  - Trading signal
  - And ultimately, translate to profit and loss (“PnL”, “P&L”), or cost (i.e. different value and risk costs differently in capital lending rate).

Data science workflow

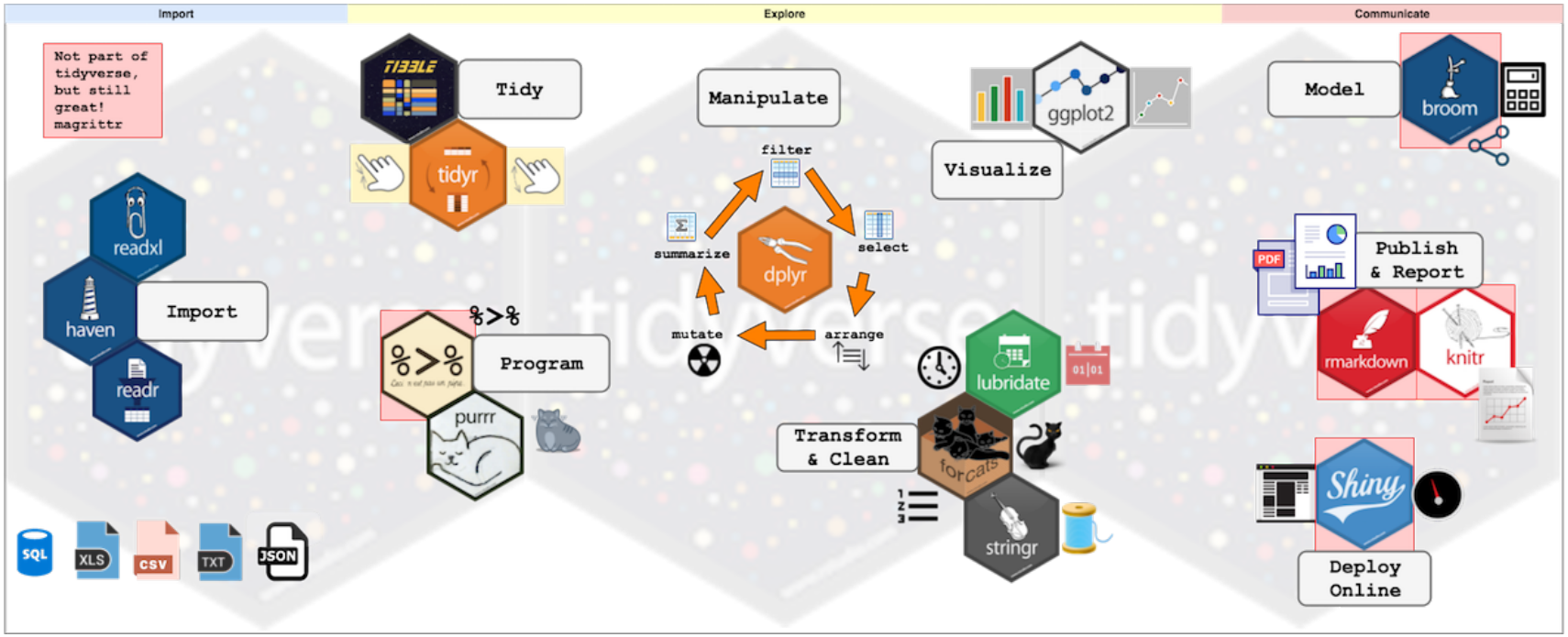
Data -> Model -> Application



- It resembles with the “Data Science” (DS) flow. Quants and DS share commonalities of working on data and model.
- That’s why “Quants” are pre-historical Data Scientist and DS are “modern quants in large”.

Programming/Internet is so powerful today!

- Programming practice has grown that there are tools for each step/stage of the workflow.
- With Internet/Web, data and computing power is also available at our fingers.



Learn the "process"

- It was difficult to do these in the past (see my later example on CAPM and Fama-French). By mastering the tools at different steps, we know the "process". Basically, we know how to get things done!
- It is not going to be too easy, too. Everyone (in the profession) has the tool. We also need to be rooted in theory and a domain application to excel.

Example: How Fama-French 3-factor model expanded CAPM?

- CAPM (1961-1966):

$$R_a = R_{rf} + \beta_a * \left(R_m - R_{rf}\right)$$

- Fama-French 3-Factor Model (1993):

$$R_{it} - R_{ft} = \alpha_{it} + \beta_1 (R_{Mt} - R_{ft}) + \beta_2 SMB_t + \beta_3 HML_t + \epsilon_{it}$$

SMB stands for "Small [market capitalization] Minus Big" and HML for "High [book-to-market ratio] Minus Low"; they measure the historic excess returns of small caps over big caps and of value stocks over growth stocks.

Question

- What step/stage do we need for implementing Fama-French 3-Factor Model?

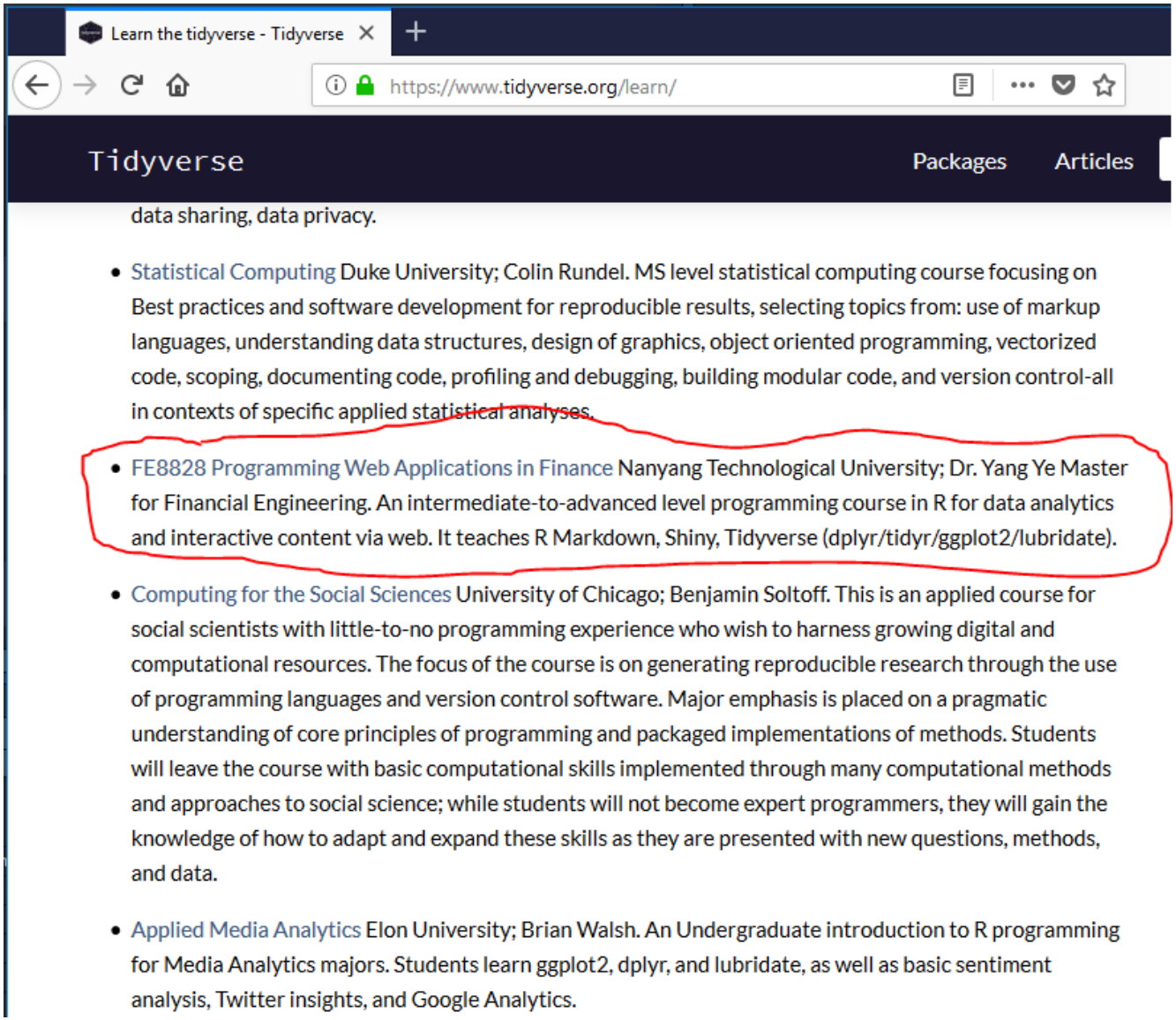
There are more endeavours to do!

- Descriptive data analysis
- EDA: exploratory data analysis
- Data cleaning
- ...
- Supply/demand analysis
- Option pricing and trading strategy
- Algorithmic trading
- Asset allocation
- Risk analytics
- Sentiment analysis
- Machine learning
- Deep learning
- ...

Our course: in detail

- Real-world finance application, asset allocation, trading strategy and derivatives valuation.
  - We will learn Programming/data science/finance in the context of Internet
  - We will build on from beginner R to intermeidate R
- You will have ample exercise in this course - learn for your own achivement.

Our course: Tidyverse with a finance flavor



What does it take?

- Pick up a habit of good analyst:
  - Use reproducible research, well-organized.
  - Have a mind for data exploration
  - Have a mind for analysis: answer is not fixed but open-ended. You need to draw conclusion and make suggestion.
  - Have a mind for strategy thinking

Course Outline: Week 1-3

- Week 1:
  - What's Internet? What's Web?
  - (Optional) Launch into the Cloud: AWS
  - R Markdown and R Shiny/1: layout
  - R Programming/1
- Week 2:
  - R Programming/2
  - R Shiny/2: Building a web app
  - dplyr/1: Data Manipulation
- Week 3:
  - dplyr/2: EDA
  - Building Financial Applications/1

Course Outline: Week 4-6

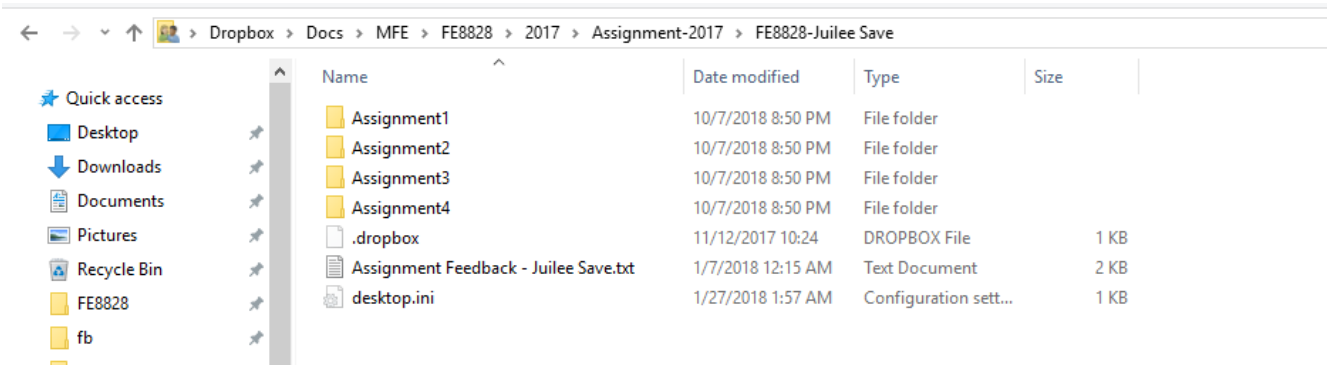
- Week 4
  - ggplot2: Data Visualization and EDA
  - R Shiny/3: Reactive
- Week 5
  - Building Financial Applications/2
  - Building Predictive Model
- Week 6:
  - Blockchain

Keep it Flexiable

- I hope to cover some ad-hoc pratical topics if feasible.

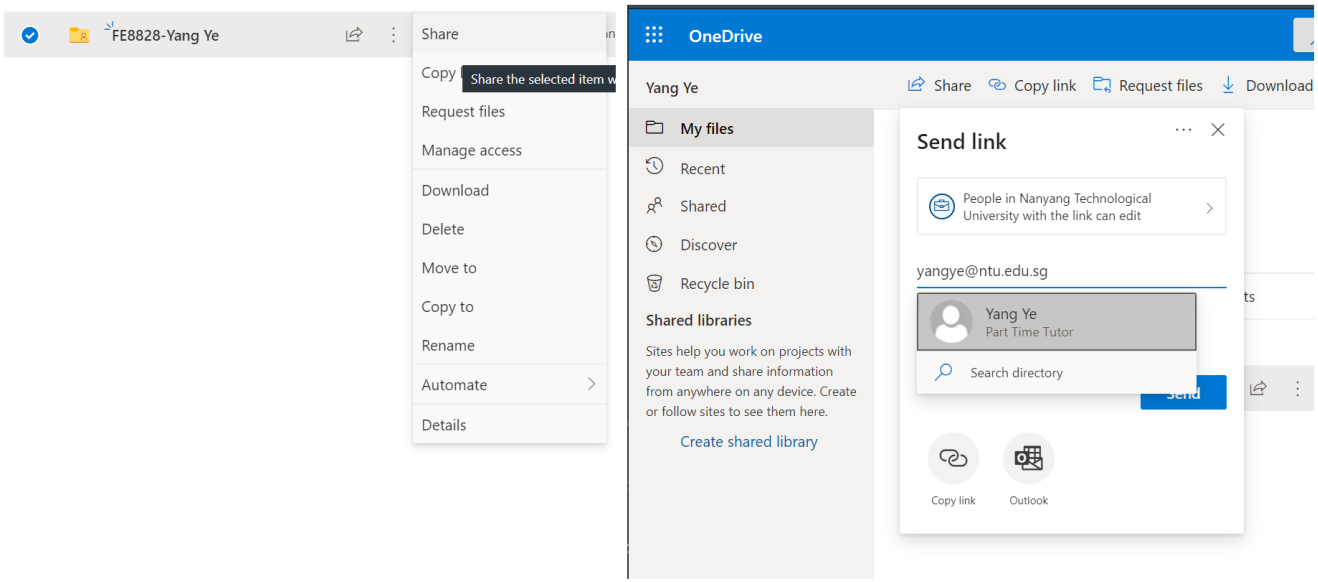
Assingment

- 4-5 individual assignments + 1 group assignment. No exam.
- Organization
  - Name your directory as FE8828-Your Name.
  - Organize your assignments into directories, e.g. Assignment 1, Assignment 2, ...

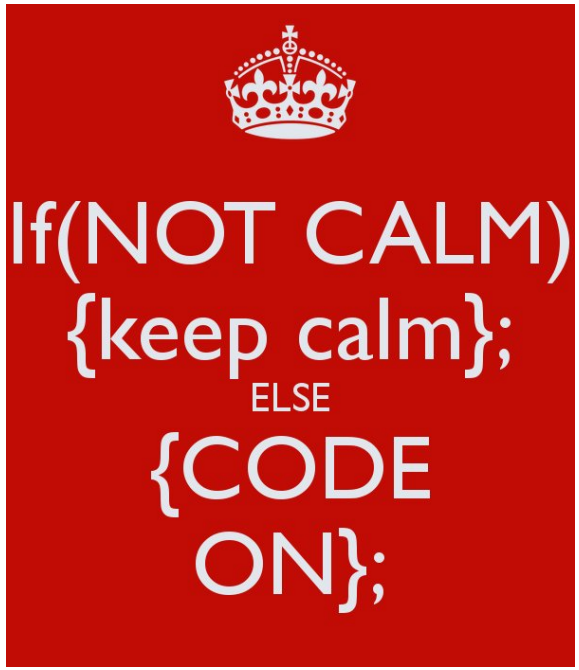


Submission by sharing

- Share the directory with *yy@runchee.com* on Google drive, or *yangye@ntu.edu.sg* with NTU One Drive.



Keep calm and code on



Questions?

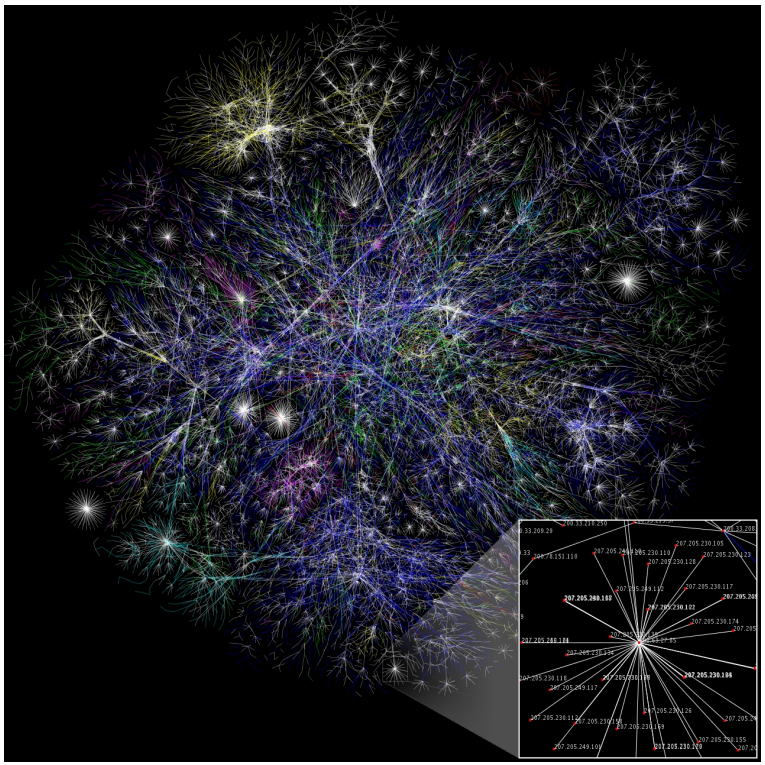
Section 2

Lecture 1: What's Internet? What's Web?

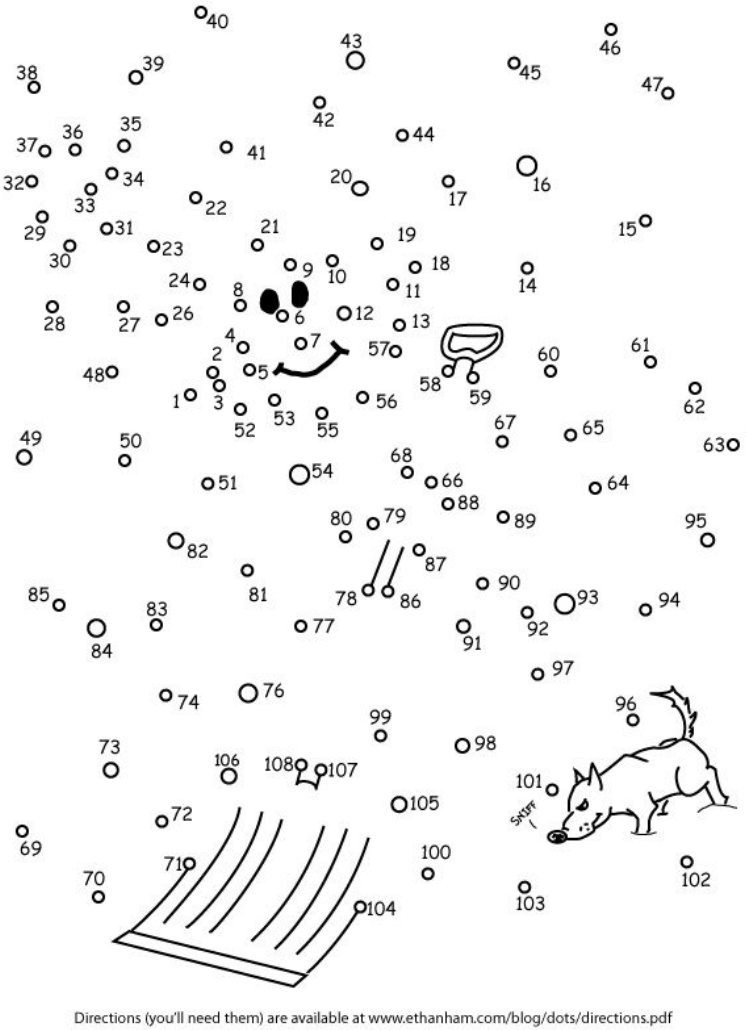
Lecture 1: What's Internet? What's Web?

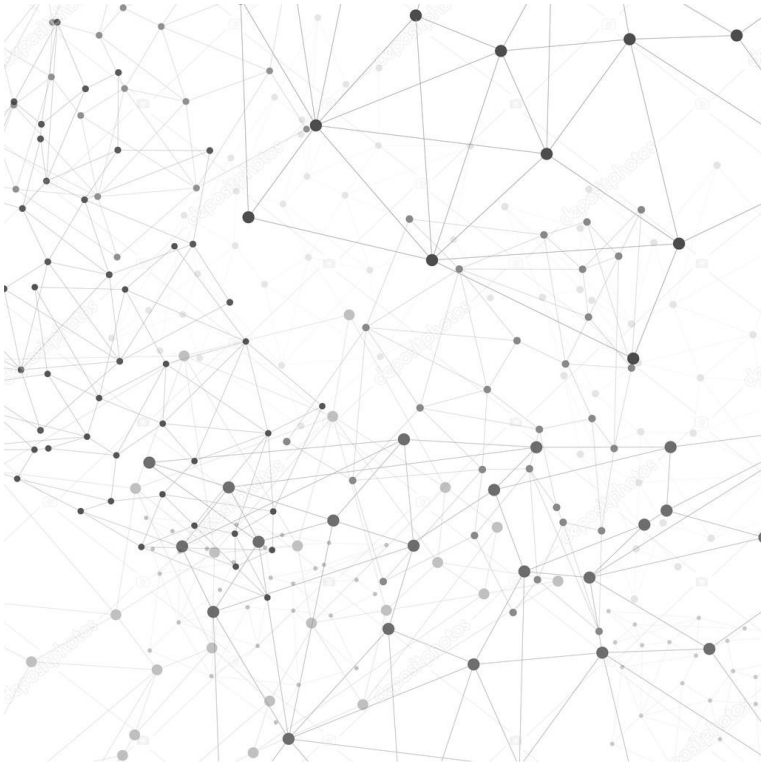
Let's pick up the jargons!

- Network
- Internet
- HTTP/HTML/Web



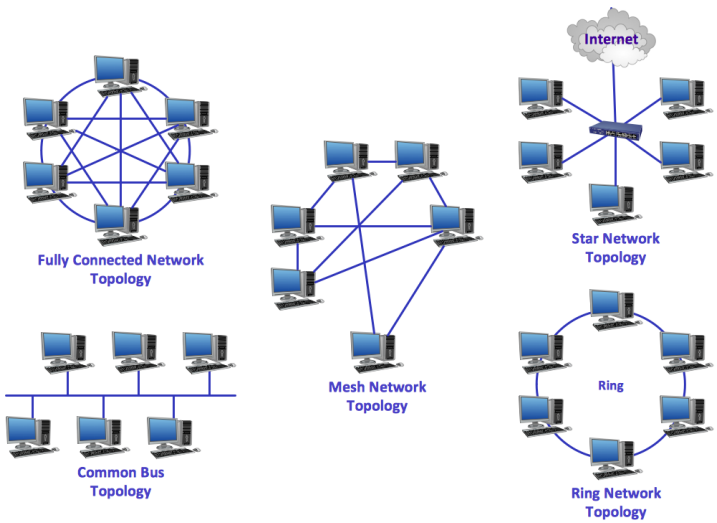
Network is to connect the dots/devices





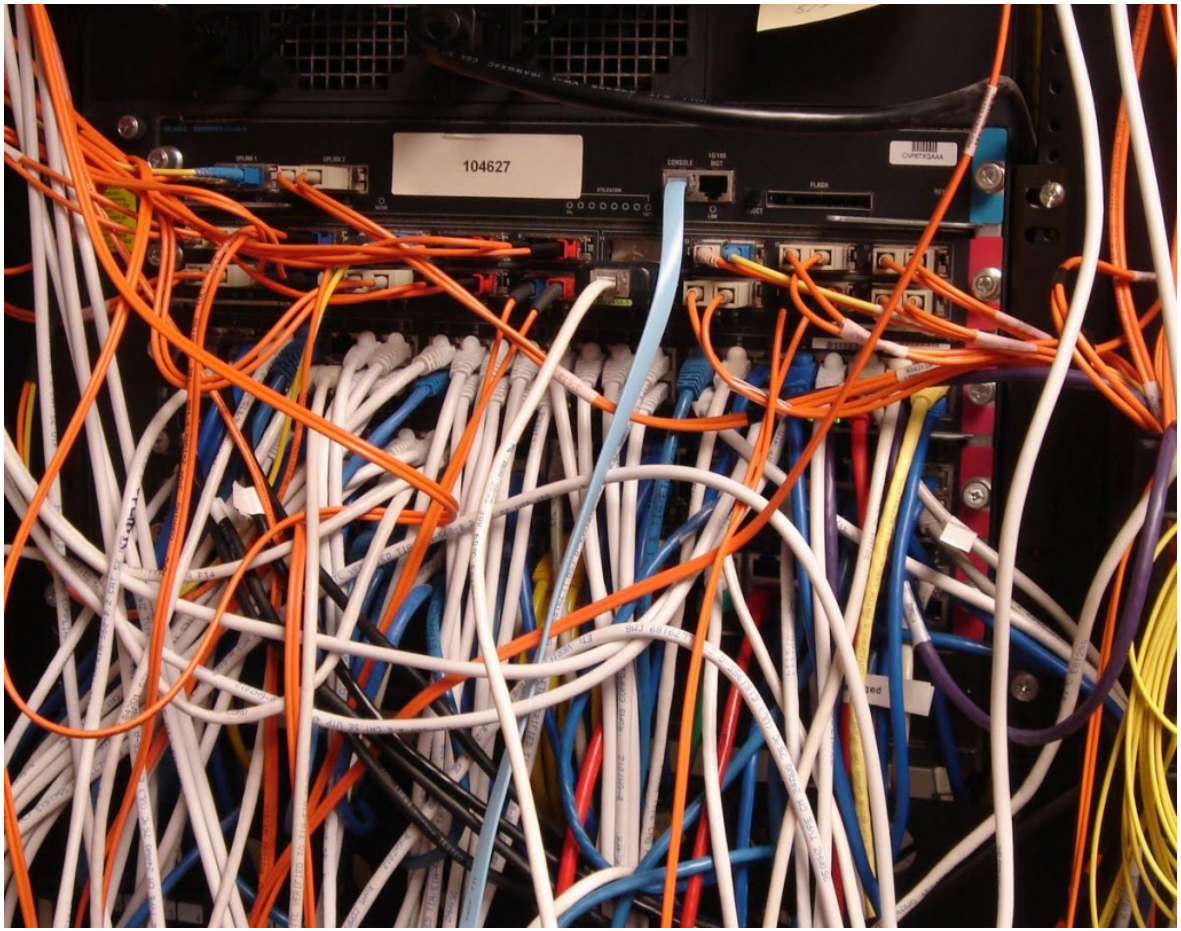
Building network

- There are many ways to connect the devices: Network topology
- Different network topology takes different way of communications.
- Fully-connected network is the most costly and robust. Ring is the cheapest but vulnerable.



Which network topology is our home Wi-Fi?

What runs inside the cables?

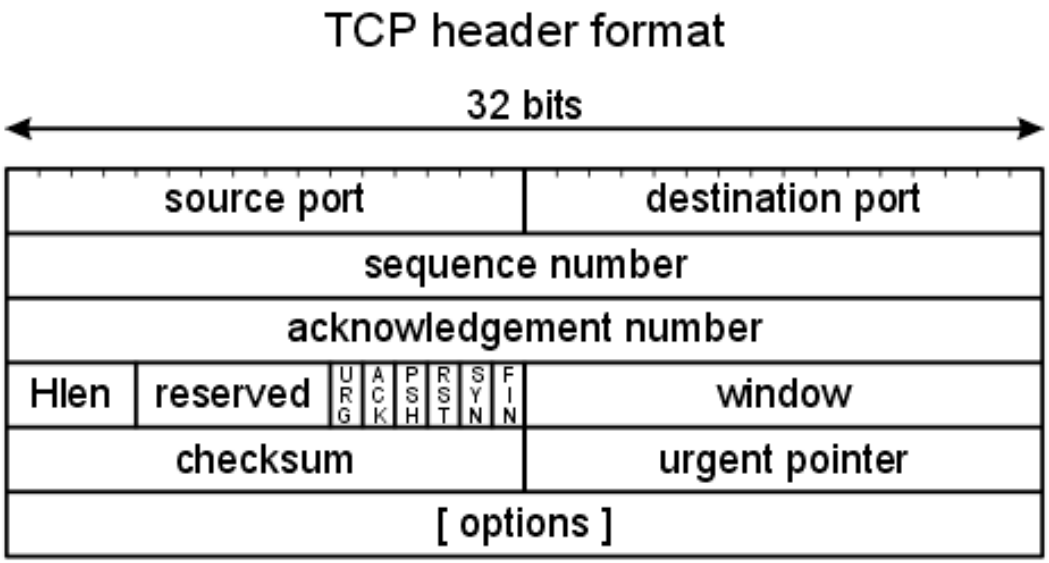


Network talks with Network Protocol

1. Information turns to *packet* according to protocol speicification.
2. *Protocol* specifies the creation, transmission and receiving of *packet*.
3. Hardware infrastructure *routes* the *packets* to the destination.

Packet

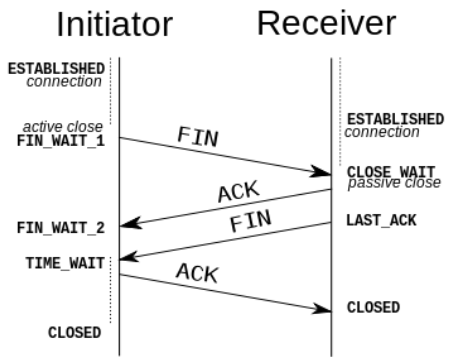
1. Information turns to packet



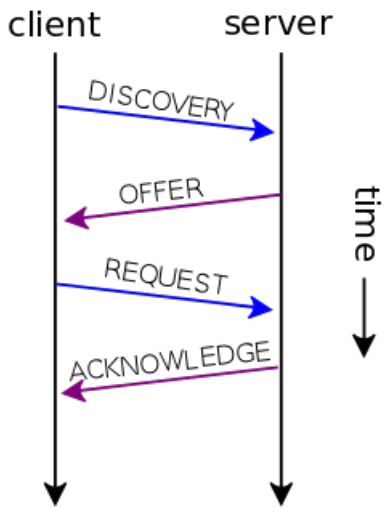
Protocol

2. Protocol designs the packet and process

TCP Session

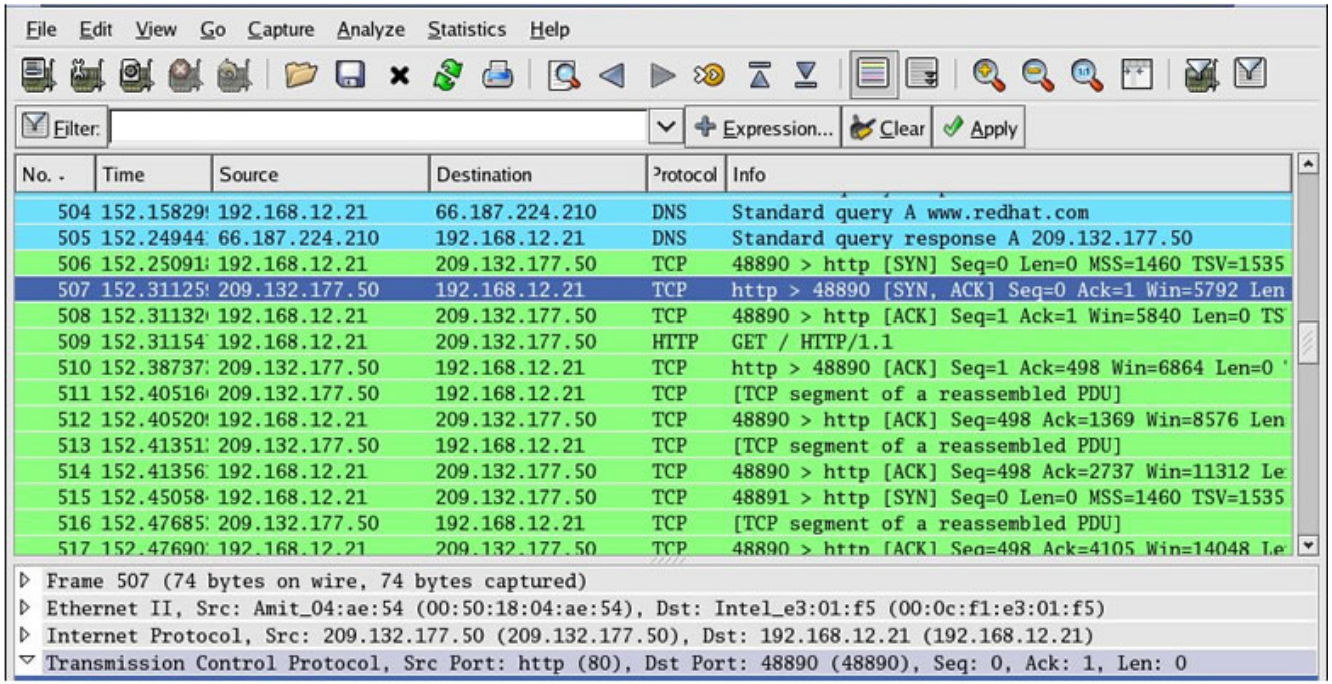


DHCP Session



Routing/Gateway

3. Infrastructure helps to *route* the packets to the destination.



TCP/IP and Internet

- What we learnt just now was implemented in large-scale in ARPANET in the 1970s by the Defense Advanced Research Projects Agency (DARPA)
- It's called the *TCP/IP* model that went on to build the Internet.

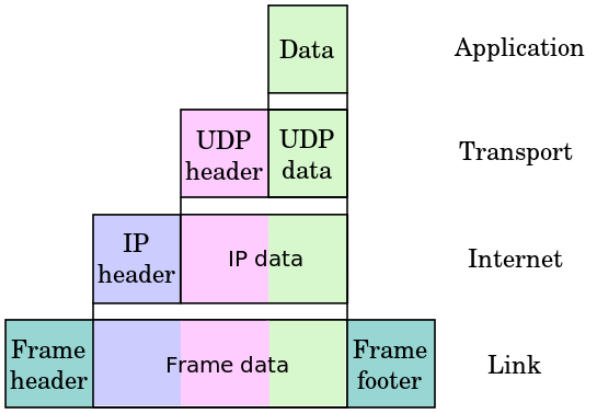
What does TCP/IP gives?

A family of protocols but what's most famous/"fundamental" is IP and TCP.

1. IP (Internet Protocol): You shall heard of "IP address", like `192.168.1.100`.
2. TCP (Transmission Control Protocol) / UDP (User Datagram Protocol)
   - TCP provides reliable, ordered, and error-checked delivery of a stream
   - UDP provides real-time transmission which can accept failure.

TCP/IP

3. Four Layers



4. Application layer runs many protocols

Internet protocol suite

Application layer

BGP · DHCP · DNS · FTP · HTTP · IMAP · LDAP · MGCP · NNTP · NTP · POP · ONC/RPC · RTP · RTSP · RIP · SIP · SMTP · SNMP · SSH · Telnet · TLS/SSL · XMPP · *more...*

Transport layer

TCP · UDP · DCCP · SCTP · RSVP · *more...*

Internet layer

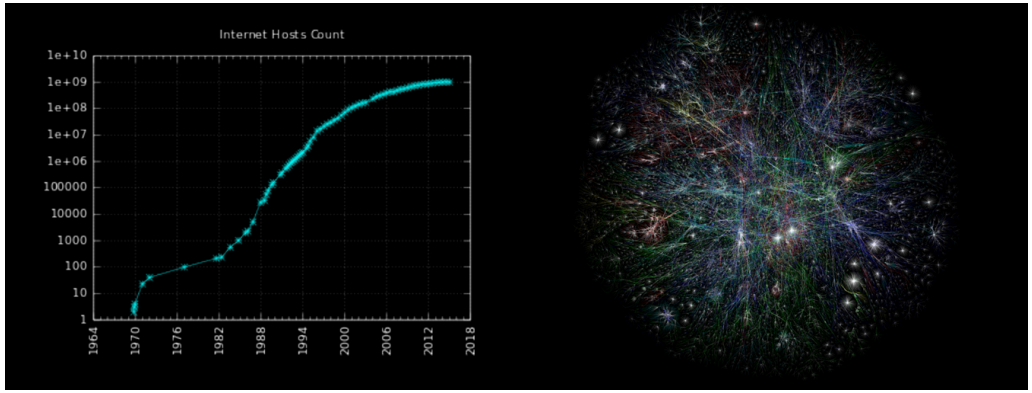
IP (IPv4 · IPv6) · ICMP · ICMPv6 · ECN · IGMP · IPsec · *more...*

Link layer

ARP · NDP · OSPF · Tunnels (L2TP) · PPP ·

Why Internet growed in size?

- A family of expandable network protocols: easy join, allows failure. That's also what we want to learn to do.



- IETF (Internet Engineering Task Force) maintains and still gets new protocol approved.

What happens after plugging cable, or turning on Wi-Fi, turn on the 5G phone?

- New network device sends a join request.
- Network gateway receives the message, allocate an IP address for the new device.
- Device accepts the IP address and uses it to label for itself. Router also knows where to send the packet.
- This auto-configure process is carried out by *Dynamic Host Configuration Protocol* (DHCP) protocol.

When it wants to visit someone on the network? DNS

- DNS is the directory service for internet.
  - We don't use *123.456.789.012* but *www.google.com*.
  - One kind of attack to Internet is to hijack/brings down Root Domain Servers for Global (8 of them) or a country's root DNS.
  - (Demo with nslookup.)

When it wants to visit someone on the network? HTTP/HTML

- Now we shall have an idea of how Internet works, let's move on to Web ("World Wide Web")
- Initiated by Tim Berners-Lee at CERN (where big collison happens in "The Large Hadron Collider") in 1989.
  - Is he supposed to be a nuclear physicist?
- Tim initiated/invented both the HTTP (protocol) and HTML (content).

HTTP Request/Response

- Request

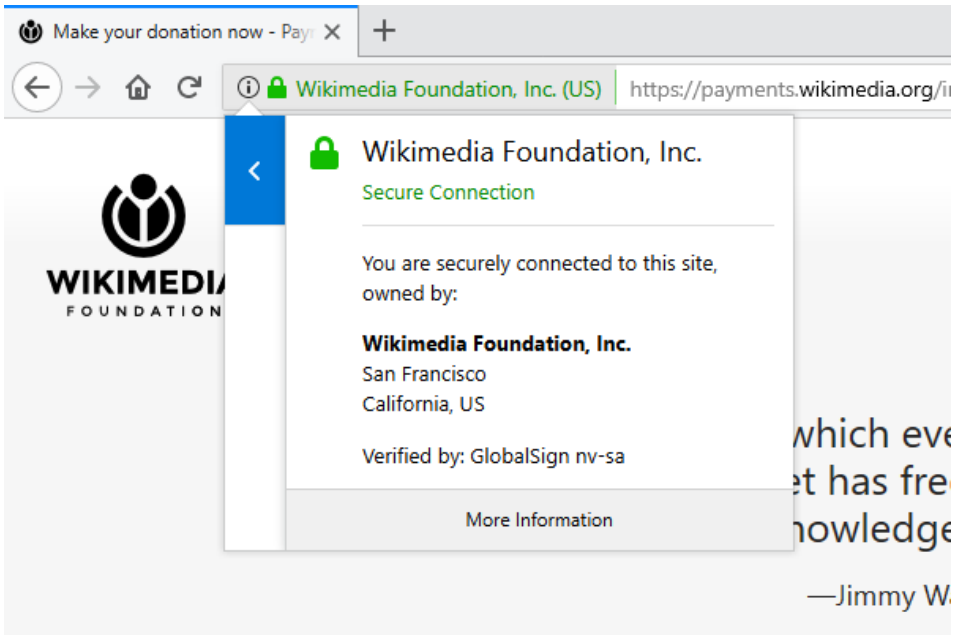
```
GET /index.html HTTP/1.1
Host: www.example.com
```

- Response

```
HTTP/1.1 200 OK
Date: Mon, 23 May 2005 22:38:34 GMT
Content-Type: text/html; charset=UTF-8
Content-Encoding: UTF-8
Content-Length: 138
Last-Modified: Wed, 08 Jan 2003 23:11:55 GMT
Server: Apache/1.3.3.7 (Unix) (Red-Hat/Linux)
ETag: "3f80f-1b6-3e1cb03b"
Accept-Ranges: bytes
Connection: close
<html>
  <head>
  <title>An Example Page</title>
  </head>
  <body>
  Hello World, this is a very simple HTML document.
</body>
</html>
```

HTTP/HTTPS/HTML

- Hypertext Transfer Protocol (HTTP) but obviously, it does file, music, anything else now.
- It's a clear text protocol. That's why we need to use HTTPS (HTTP on SSL) to secure the communication.
- In browser, you can see the green lock in address bar. This is about digital certificate, associated with crytography and authentication. Another topic.



Web

When you have HTML and URL (Uniform Resource Locator), Web is born.

- Website: https://en.wikipedia.org/
  - Document: https://en.wikipedia.org/wiki/World_Wide_Web
- Resource: https://en.wikipedia.org/wiki/World_Wide_Web#/media/File:Web_Index.svg

How this resource (URL) is used in document (HTML).

```
<div class="thumbinner" style="width:302px;">
  <a href="/wiki/File:Web_Index.svg" class="image">
  <img alt="" src="//upload.wikimedia.org/wikipedia/commons/thumb/6/65/Web_Index.svg
width="300" height="154" class="thumbimage"  />
  </a>
  </div>
```

Web Browser

First generation (1993)

Web application

- Static v.s. Dynamic
- Dynamic website display content based on user input.
- Supported by HTML/CSS/JavaScript. HTML 5, CSS 3 and JavaScript 7 .
- App also uses HTML/CSS/JS.

Web application

- Why it is important? Needless to say. It is not 1995 anymore.
  - Easy to deploy: no copy needed
  - Runs fast: every browser is optimized
  - Easy to develop: less effort than Mobile App and cross-platform.

What would we like to do?

Now comes the final part

- With the Internet infrastructure, we can get finance data (price, economic indicators) easily
- We can use the tools to process them, pass them through model and computing engine
- AS the result, we will have an application.
- We don't need to write HTML/CSS/JavaScript. We will write R and it assembly HTML/CSS/JavaScript for us.

Take-home

Why the Internet has succeeded?

- Information flows by packet.
- Protocol enables easy join, allows failure.
  - Local device just needs to send the packet
  - Nework routers/gateways does the route/transmission to the destination.
  - Scalable and Efficient

Why Web has succeeded?

- Web helps to locate universal resource.
- Web helps to organize them in one place.

Take-home

Finance application

- Any finance application is a data application.
- Internet gave us the access to data and computing power.

Inspiration

- Internet is a recent invention that's just 30-something years old.
- Quant finance is also young: (Bachelier 1900s), Markowitz 50s, CAPM 60s, APT/Black-Scholes 70s, Quant finance 80s, Factor research 90s, High-Frequency trading 00s, GFC/QE 08, Robo-invest/ML/DL 10s, post-COVID 20s (hope not too long) ...
- Both are journeies of inventions and mavericks that inspire you to live to the future of quant research.
- We are learning/using recent inventions and have the opportunities to brings them forward.

Section 3

Lecture 2: Launch into the Cloud: Amazon Web Services

Lecture 2: Launch into the Cloud: Amazon Web Services

- Sign-up for AWS Account
- Setup AWS for EC2
- Launch EC2
- Running R

Disclaimer:

1. I am not owning Amazon shares directly or indirectly.
2. I don't plan to long AMZN during the course of this course.
3. I am not working for Amazon and I don't get paid by doing this except receiving AWS educate credit.

Section 4

Lecture 3: R Markdown and R Shiny/1: layout

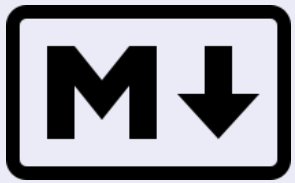
Introduction

- `Markdown` is a format that is easy to read and can be converted to other formats, HTML, PDF, Word, Slides.
- R Studio extends it further to create R notebook, interactive document and web application, which is `R Markdown`.
- *Shiny* is a web programming framework in R. We use it extensively in this course. We begin with the layout part.

Markup and Markdown

- Document stores information.
- Web is a superset of interlinked documents.
- HTML is a markup language, built for machines.
- Markdown is for humans to write doc, with minimal added to decorate it, created by John Gruber in collaboration with Aaron Swartz in 2004.

```
A Markdown-formatted document should be publishable as-is,
as plain text, without looking like it's been marked up
with tags or formatting instructions.
                                                - John Gruber
```



Markdown example

```
---
title: My first bitcoin
subtitle: and how I bought a pizza!
author: "Gru"
date: "Jul 9, 2010"
---

# How I bought it

I found someone was selling _10000_ on ebay for __$30__.
I think that's

- cool
- fun
- hacker

# How I used it

I forgot to bring my wallet the other day.
So I used **the bitcoins** to buy some pizza.

![Pizza](../notes/imgs/bitcoin-pizza.png)
```

Markdown output example

title	subtitle	author	date
My first bitcoin	and how I bought a pizza!	Despicable me	Jul 9, 2010

How I bought it

I found someone was selling *10000* on ebay for **$30**. I think that's

- cool
- fun
- hacker

How I used it

I forgot to bring my wallet the other day. I was hungry so I used **the bitcoins** to buy some pizza.

Markdown: Header and Code

Headers

More hashtag, deeper level.

```
# Header1
## Header2
### Header3
```

Code

Give four spaces before it

```
    if (a > 0) {
      print(a)
    }
```

Markdown: List

```
* First paragraph.
Continued.

* Second paragraph. With a code block, which must be indented
eight spaces:

        { code }
```

- First paragraph. Continued.
- Second paragraph. With a code block, which must be indented eight spaces:

Markdown: Multi-level list

Put four more spaces for each level.

```
* fruits
    + apples
        - macintosh
        - red delicious
    + pears
* vegetables
    + broccoli
```

- fruits
  - apples
    - macintosh
    - red delicious
  - pears
- vegetables
  - broccoli

Markdown: Ordered List

Put 4 more spaces for each level.

```
#. Chapter 1
    #. Section 1.1
    #. Section 1.2
#. Chapter 2
#. Chapter 3
```

1. Chapter 1
    1. Section 1.1
    2. Section 1.2
2. Chapter 2
3. Chapter 3

Table

```
| Tables         | Are            | Cool  |
| -------------- |:--------------:| -----:|
| col 3 is       | right-aligned  | $1600 |
| col 2 is       | centered       |   $12 |
| zebra stripes  | are neat       |    $1 |
```

Tables	Are	Cool
col 3 is	right-aligned	$1600
col 2 is	centered	$12
zebra stripes	are neat	$1

Markdown: Inline formatting

Emphasis

To emphasize some text, surround it with *s or _, like this:

```
This text is \_emphasized with underscores\_, and this
is \*emphasized with asterisks\*.
Double * or _ produces strong emphasis:

This is \*\*strong emphasis\*\* and \_\_with underscores\_\_.
```

This text is *emphasized with underscores*, and this is *emphasized with asterisks*.
Double * or _ produces strong emphasis.
This is **strong emphasis** and **with underscores**. A * or _ character surrounded by spaces, or backslash-escaped, will not trigger emphasis.

Strikthrough

This ~~is deleted text.~~
This ~~is deleted text.~~

Markdown: formatting

Superscripts and subscripts

H~2~O is a liquid. 2^10^ is 1024.
H_2O is a liquid. 2^{10} is 1024.

Verbatim. inline code

Use backtick ‘ (the key to the left of 1)
What is the difference between ‘a = 1‘ and ‘a <- 1‘?
What is the difference between `a = 1` and `a <- 1`?
Note:

- If the verbatim text includes a backtick, use two backticks.
- Use \\ to turn off \

Links

<http://google.com>

http://google.com

Markdown: Images

A link immediately preceded by a ! will be treated as an image. The link text will be used as the image's alt text:

```
![Pizza](imgs/bitcoin-pizza.png)
```

Figure 1: Pizza

Markdown: Formula

MathJax. Use LaTex syntax. There are many online references.

- Inline with text, `$x = {-b \pm \sqrt{b^2-4ac} \over 2a}$`, $x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$
- Or, Centered, `$$\sum_{i=1}^n X_i$$`

$$\sum_{i=1}^{n} X_i$$

Markdown Support in R Studio

- `R Markdown` is a extension to Markdown that you can execute code among the code.
- It's with suffix **.Rmd**. R Studio has good support for it.
- Reference
  - R Markdown Cheat Sheet: `Help > Cheatsheets > R Markdown Cheat Sheet`,
  - R Markdown Reference Guide: `Help > Cheatsheets > R Markdown Reference Guide`.
- Create via `File > New File > R Markdown`.

R Markdown Document example

````
---
title: "Data Analysis Report"
author: "Yang Ye"
date: "October 23, 2018"
output: html_document
---

```{r setup, include=FALSE}
knitr::opts_chunk$set(echo = TRUE)
```

## Report
```{r cars}
summary(cars)
```

## Including Plots
```{r pressure, echo=FALSE}
plot(pressure)
```
````

R Markdown Document Output

In the header, you can change the output to other types:

- html_document
- pdf_document
- word_document

After all, press `Ctrl+Shift+K` or Click `Knitr`

Code block for R Markdown

- Embed code (R, Python, etc.) in R Markdown
- R code can be inline. For example, to generate a random number everytime, include this `` `r runif(1, 0, 1)` ``, 0.4369457.
- R code can exist as block, run and show its results. `Calculate_7` is the chunk name. It's optional to give a chunk name. If included, each code chunk needs a distinct name. It's usually best to give each code chunk a name, for easier debug.

Code chunk example:

````
```{r Calculate_7}
a <- 3
b <- 4
print(a + b)
```
````

Result

```
## [1] 7
```

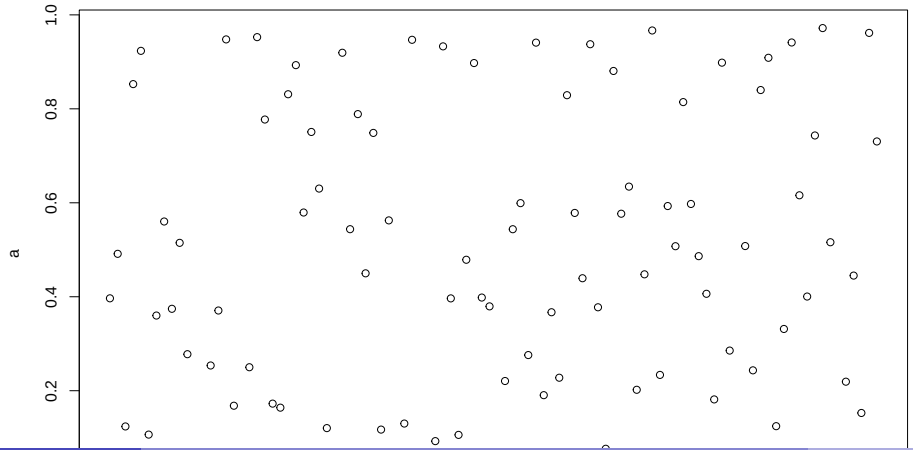
Chunk options

- *echo* is to decide whether to display code, default is `FALSE`.
- *results* is to decide whether to display result, default is "markup", set to "hide" to hide.
- *include* is to hide both code and result, default is `FALSE`.

````
```{r cars, echo = TRUE}
a <- runif(100, 0, 1)
```
````

```r
a <- runif(100, 0, 1)
```

````
```{r plot}
plot(a)
```
````



R Markdown: Table

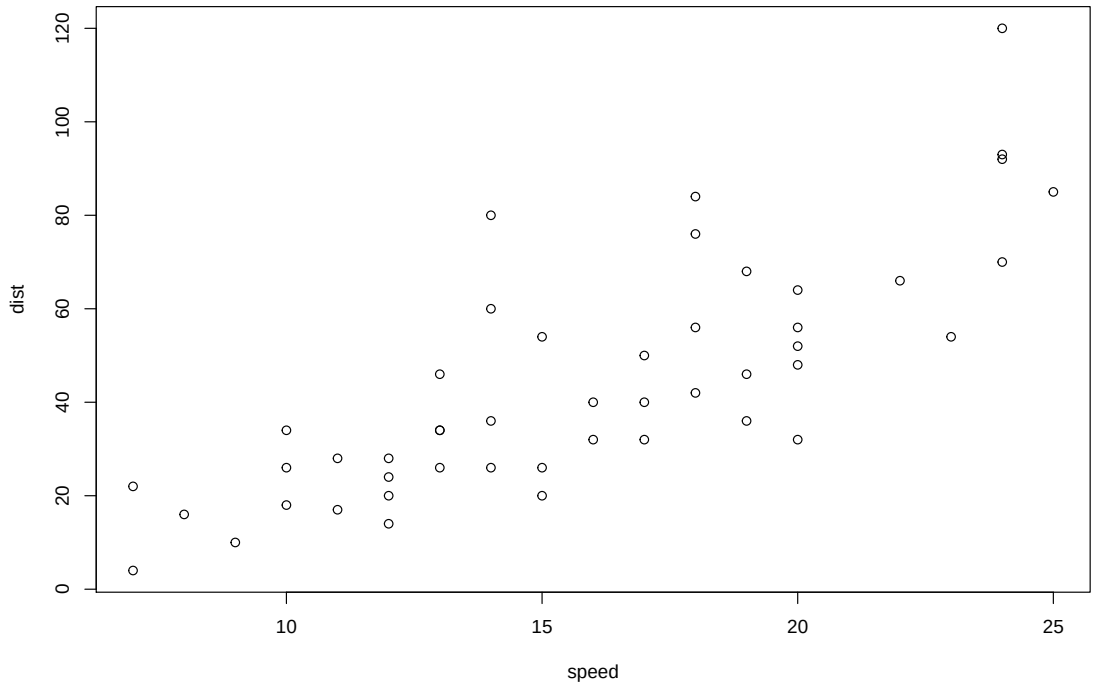
```
```{r kable}
knitr::kable(
  mtcars[1:5, ],
  caption = "A knitr kable."
)
```
```

Table 2: A knitr kable.

	mpg	cyl	disp	hp	drat	wt	qsec	vs	am	gear	carb
Mazda RX4	21.0	6	160	110	3.90	2.620	16.46	0	1	4	4
Mazda RX4 Wag	21.0	6	160	110	3.90	2.875	17.02	0	1	4	4
Datsun 710	22.8	4	108	93	3.85	2.320	18.61	1	1	4	1
Hornet 4 Drive	21.4	6	258	110	3.08	3.215	19.44	1	0	3	1
Hornet Sportabout	18.7	8	360	175	3.15	3.440	17.02	0	0	3	2

R Markdown example: Plot

```
```{r plot1, echo = FALSE}
a <- filter(cars, speed > 4)
plot(a)
```
```



R Shiny

- To start, use R Studio.
- File > New File > Shiny Web App...
- Choose single file
- Give a name and folder
- Ctrl+Shift+S or “Run App”

UI First

I removed everything in functions `server` and `ui`. This is the minimal Shiny. (shiny-1-empty.R)

```
library(shiny)

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

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

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

Sidebar Layout

Let's add a minimal sidebarLayout (shiny-2-sidebar.R)

```
library(shiny)

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

  fluidPage(sidebarLayout(
    sidebarPanel("This is a panel on the side"),
    mainPanel("This is the main panel")
  )),

  fluidPage(sidebarLayout(
    sidebarPanel("This is a panel on the side"),
    mainPanel("This is the main panel")
  ))
)

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

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

fluidPage

- fluidPage means to place the controls from left-right, top-down order.
- `fluidPage` function can take any number of input parameters.

```
fluidPage(sidebarLayout(
    sidebarPanel(),
    mainPanel()
))
```

Add some tags

- `titlePanel("Hello Shiny!")`, `h1("Introduction to Layout")`, `h2("Sidebar Layout")` (shiny-3-sidebar-min.R)

```
library(shiny)

# Define UI for application that draws a histogram
ui <- fluidPage(
  fluidPage(
    titlePanel("Hello Shiny!"),
    sidebarLayout(
      sidebarPanel(
        h1("Introduction to Layout"),
        h2("Sidebar Layout")
      ),
      mainPanel(
        img(src = "p19-Hero-Image-796x398.jpg")
      )
    )
  )
)

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

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

Sidebar layout with bar on the right

```
fluidPage(
    sidebarLayout(position = "right",
    sidebarPanel(),
    mainPanel()
    )
)
```

More tags: Sidebar with more tags (shiny-3-sidebar.R)

```
library(shiny)

# Define UI for application that draws a histogram
ui <- fluidPage(
  fluidPage(
    titlePanel("Hello Shiny!"),
    sidebarLayout(
      sidebarPanel(
        h1("Introduction to Layout"),
        h2("Sidebar Layout"),
        a("A link to Google", href="http://www.google.com"),
        # unordered list
        tags$ul("About",
          tags$li("Who are we"),
          tags$li("What we do")
        ),
        # ordered list
        tags$ol("Steps",
          tags$li("Write"),
          tags$li("Run")
        )
      ),
      mainPanel(
        img(src = "p19-Hero-Image-796x398.jpg")
      )
    )
  )
)

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

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

Each tag is a function.

```
h1("A header")
p("some text as a paragraph")
a("A link to Google", href="http://www.google.com")
img(src = "p19-Hero-Image-796x398.jpg", width = "100%")
tags$ul("title", tags$li("Item 1"), tags$li("Item 2"))
tags$ol("Step", tags$li("Item 1"), tags$li("Item 2"))
```

Note:

- For image, you need to create a sub-directory `www` together with the R source file. Place the file under it.
- tags is a list of functions. To avoid name conflict, I prefer to use `tags$img()`, even `img()` is available to use.

Panels

`titlePanel()` and `wellPanel()` (shiny-4-wellPanel.R)

```
library(shiny)

# Define UI for application that draws a histogram
ui <- fluidPage(
    titlePanel("Hello Shiny!"),
    sidebarLayout(
      sidebarPanel(
        h1("Well 1"),
        wellPanel(
          h2("Well 1.1"),
          actionButton("goButton", "Go!")
        ),
        h1("Well 2"),
        wellPanel(
          h2("Well 2.1"),
          actionButton("goButton2", "Go!")
        )
      ),
      mainPanel(
      )
    )
  )

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

# Run the application
```

Navlist panel (shiny-5-navPanel.R)

```
library(shiny)

# Define UI for application that draws a histogram
ui <- fluidPage(
  fluidPage(
    titlePanel("Hello Shiny!"),
    navlistPanel(
      "Header A",
      tabPanel("Section 1",
               h1("Section 1"),
               p("This is section 1. First lecture in FE8828.")),
      tabPanel("Section 2",
               h1("Section 2")),
      "Header B",
      tabPanel("Section 3",
               h1("Section 3")),
      "-----",
      tabPanel("Component 5")
    )
  )
)

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

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

tabPanel (shiny-6-tabPanel.R)

```
library(shiny)

# Define UI for application that draws a histogram
ui <- fluidPage(
  fluidPage(
    titlePanel("Hello Shiny!"),
    tabsetPanel(
      tabPanel("Plot", h1("plot")),
      tabPanel("Summary", h1("summary")),
      tabPanel("Image", img(src = "p19-Hero-Image-796x398.jpg"))
    )
  )
)

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

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

navBar (shiny-7-navbar.R)

```
library(shiny)

ui <- fluidPage(
    navbarPage(title = "Runchee Technology",
               tabPanel("Product",
                        titlePanel("Hello!"),
                        "One more thing!",
                        p("another paragragh")),
               tabPanel("About us",
                        fluidPage(titlePanel("Hello!"),
                                  "Exordinary people"))
               ,
               navbarMenu(title = "Contact Us",
                          tabPanel("Address", "3/4 platform"),
                          tabPanel("Phone", "+123.456")
               )
    )
)

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

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

Column-based layout (shiny-8-column.R)

- Caveat: There is fluidRow, but no fluidColumn.
- Column counts always add up to 12 = 4 + 6 + 2; otherwise, it will appear in the next line.

```
library(shiny)

ui <- fluidPage(
  fluidPage(
    fluidPage(
      titlePanel("Hello Shiny!"),
      fluidRow(
        column(4,
               wellPanel(
                 dateInput("date", "How's weather today?")
               )
        ),
        column(6,
               h3("Plot"),
               wellPanel(plotOutput("distPlot"))
        ),
        column(2, h3("Extra"),
               wellPanel(plotOutput("extraPlot"))
               )
      )
    )

    )
)

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

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

Composition layout: Top and Down (shiny-10-composite.R)

```
library(shiny)
library(ggplot2)

ui <- fluidPage(
  fluidPage(
    fluidPage(
      title = "Diamonds Explorer",
      fluidRow(
        column(12,
               img(src = "p19-Hero-Image-796x398.jpg", width = "100%")
               )
      ),

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

R Markdown can also contain Shiny (shiny-mfe-example.Rmd)

````
---
title: "MFE FE8828 Assignment 1"
date: 2018-11-03
output: html_document
runtime: shiny
---

```{r setup, include = FALSE}
```

# Use echo = TRUE for assignment is an exception, so code is visible.
```{r, echo = TRUE}
wellPanel("Inputs",
          numericInput("fav_num", "What's your favorite number?", 3))
```
````

Inputs

What's your favorite number?

This is interactive document. –>

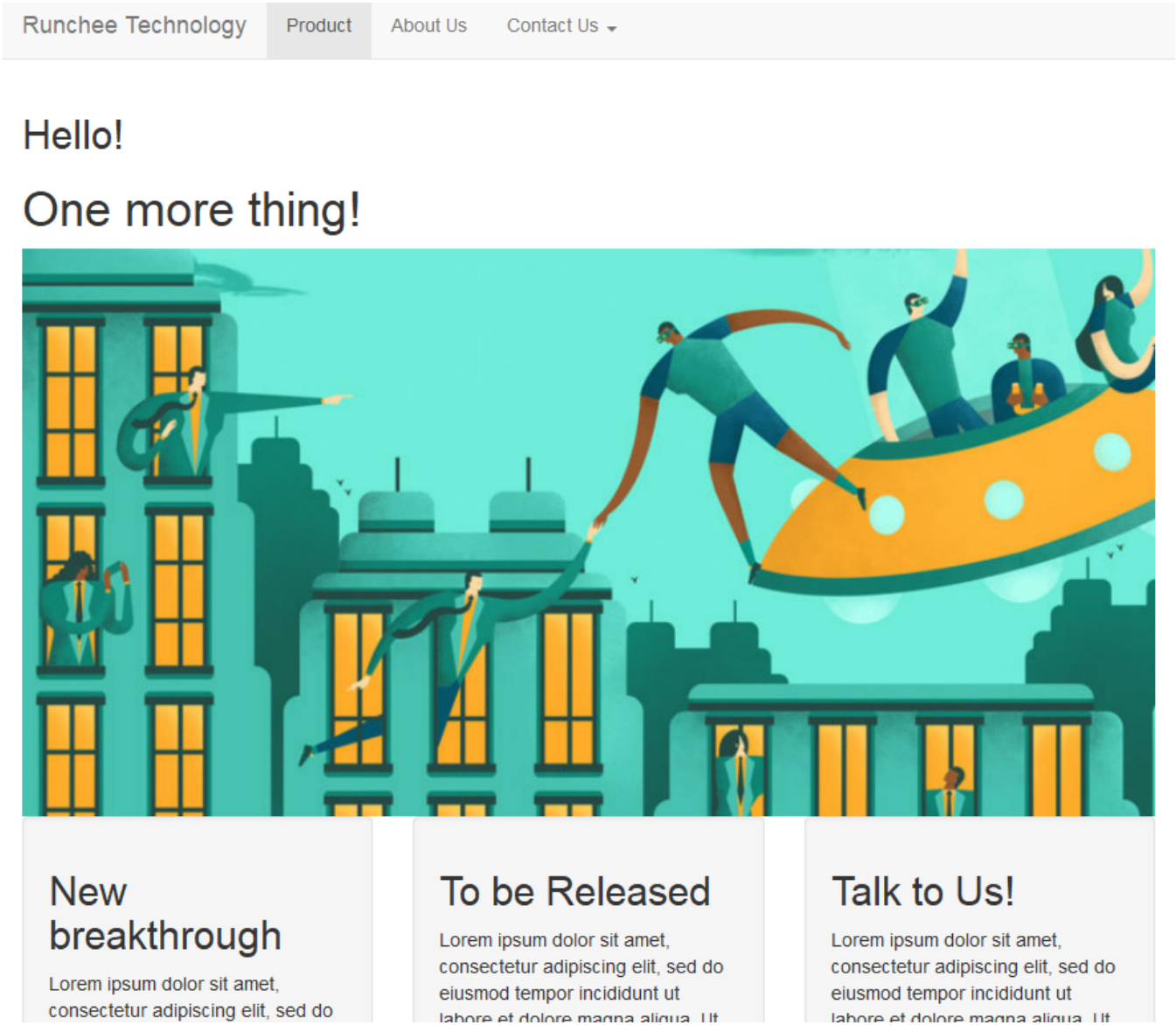
Take-home

- Markdown is a simplified way to write formated documents.
- R Markdown can embed code and results. It can mix code and documentation, speed up research progress.
- R Shiny is a web framework. One tag is one function. Easy to compose web page.

Assignment

- Create a website (perhaps a single *.R* file) with Shiny using one of the layouts
  - You are starting a company to offer.
  - Decide what you want to do
  - Create three pages. Name the pages depending on what you want to do.
    e.g. Product, About Us and Contact Us
  - Use different layouts for the pages: sideBar, column-based layout, Navlist.
  - Be creative!

Demo website with navBar style.



Section 5

Lecture 4: R Programming

R programming

Let's review some R basics and progress to intermediate level. We have following topics:

- Vector/Matrix/String/Date/Time
- Data Frame
- List
- Load/Save
- Anonymous function ...

R: Vector

```
# Create a vector from number
v <- c(1, 3)
v[1] <- 3
v
## [1] 3 3
```

```
# repeat 100 for 10 times.
rep(100, 10)
##  [1] 100 100 100 100 100 100 100 100 100 100
```

R: Matrix

```
# create matrix of 3x4
mat <- matrix(2, 3, 4)
mat
##      [,1] [,2] [,3] [,4]
## [1,]    2    2    2    2
## [2,]    2    2    2    2
## [3,]    2    2    2    2
# set first row to 4
mat[1, ] <- 4
# set element (2, 2) to 6
mat[2, 2] <- 6
```

Find element(s) in Vector

- which()
- match()
- %in%

```
data <- 10:1
match(c(1, 3), data)
## [1] 10  8
data[match(c(1, 3), data)]
## [1] 1 3
# Equivalently, ...
which(1 == data | 3 == data)
## [1]  8 10
data[which(1 == data | 3 == data)]
## [1] 3 1
```

Check whether element exists

- FALSE case when element doesn't exist

```
match(c(11, 31), 10:1)
## [1] NA NA
which(11 == 10:1 | 31 == 10:1)
## integer(0)
length(which(11 == 10:1 | 31 == 10:1)) # When length(result) == 0,
## [1] 0
```

- any() and all()

```
if (all(c(1, 33) %in% 1:3)) {
  cat("Found all\n")
}

if (any(c(1, 33) %in% 1:3)) {
  cat("Found one/some.\n")
}
## Found one/some.
```

Random

```
# Normal distribution random number
rnorm(3, mean = 10, sd = 3)
## [1] 11.532142  9.143481  7.909362
```

```
# Uniform distribution random number
runif(3)
## [1] 0.6981622 0.2276544 0.3544616
```

```
# Sample
sample(1:10, 10, replace = FALSE)
##  [1]  6  7  5  8  4  3  9  2  1 10
# To Be/Not to Be
sample(c(T, F), 10, replace = TRUE)
##  [1] FALSE  TRUE  TRUE FALSE FALSE  TRUE  TRUE  TRUE FALSE FALSE
# Throw a dice
sample(1:6, 10, replace = TRUE)
##  [1] 3 4 5 4 4 4 5 6 1 4
```

Print

- There is `print()` but I use most `cat(paste0(..., "\n"))`.
- `"\n"` is appended to the end to create a line break.
- `paste0()/paste()` can use to create new strings from any data types.
- `paste0()` combines any thing without space. `paste()` uses space, by default.
- `paste0()/paste()` with `collapse` helps with vector to print them in one line.
- `paste0()/paste()` works with all types of data.

```
x <- c(Sys.Date(), Sys.Date(), Sys.Date())
cat(paste0("Current dates is ", x, ".\n"))
## Current dates is 2020-09-17.
##  Current dates is 2020-09-17.
##  Current dates is 2020-09-17.
cat(paste0("Current dates is ", paste0(x, collapse = ", "), ".\n"))
## Current dates is 2020-09-17, 2020-09-17, 2020-09-17.
```

String

```
# sub-string
# substr(x, start, stop)
substr("The fox jumps.", 6, 6 + 5 - 1)
## [1] "ox ju"
```

```
# paste0/paste to concatenate string/convert to string
new_string <- paste0("This is ", "cat")
new_string <- paste0("This is ", "cat", sep = "a")
new_string <- paste0(1:3, sep = "a")
```

```
# toupper/tolower
toupper("big")
## [1] "BIG"
tolower("LOWER")
## [1] "lower"
```

Find/Replace in String

```
# grepl: Find, returns T or F
grepl("A", "ABC", fixed = TRUE)
## [1] TRUE
grepl("D", "ABC", fixed = TRUE)
## [1] FALSE
```

```
# sub: replace for one time
# sub(pattern, replace, string,...)
# fixed = TRUE means use fixed string. Not regular expression
sub("D", "ABC", "DDD", fixed = TRUE)
## [1] "ABCDD"
# gsub: replace for all
gsub("D", "ABC", "DDD", fixed = TRUE)
## [1] "ABCABCABC"
```

Find/Replace String with Regular Expression (RE)

If you start to use *regular expression*, sub/grepl becomes super powerful. They are default with RE turned on with default value for `fixed = FALSE`.

```
# If we need to find `Start` appearing the beginning of the string
grepl("^Start", "Start with me")
## [1] TRUE
grepl("^Start", "me Start")
## [1] FALSE
```

```
# To find something in the end
sub("X$", "Z", "XYZ ends with X")
## [1] "XYZ ends with Z"
```

Match with Regular Expression (RE)

```
sub("[^\\_]+\\_.*", "", "USDCNY_M1")
## [1] ""
```

- `[^\\_]`: Character not containing _. Because _ is a special character, we quote it with two backslashes.
- `+`: One or more
- `.`: Any character
- `*`: none or more.

Extraction with Regular Expression (RE)

```
# Rough cut
sub("([^\\_]+)\\_.*", "\\1", "USDCNY_M1")
## [1] "USDCNY"
```

```
# Nice cut
sub("([^\\_]+)\\_(.*)", "\\1 \\2", "USDCNY_M1")
## [1] "USDCNY M1"
```

```
# Wonderful cut
sub("([^\\_]+)\\_([[:alpha:]])([[:digit:]])", "\\1 \\2 \\3", "USDCNY_M1")
## [1] "USDCNY M 1"
```

Regular Expression's Cheatsheat https://www.rstudio.com/resources/cheatsheets/

Date

```
# Create date
dt1 <- as.Date("2021-11-03")
dt1
## [1] "2021-11-03"
dt2 <- Sys.Date()
dt2
## [1] "2020-09-17"
```

```
library(lubridate)
```

```
# Date is such a central role in finance.
# More function about date can be found in package `lubridate`
# Create date with lubridate, a package which provides lots of date functions.
ymd(20210910)
## [1] "2021-09-10"
ymd("20210910")
## [1] "2021-09-10"
```

Date: format code

We can use codes for convert date from/to string.

- %Y/%y: four-digit year/two-digit year
- %m: month in number
- %b/%B: month in abbreviation/full, i.e. Jan/January.
- %d: day

```
format(Sys.Date(), format = "%Y/%m/%d")
## [1] "2020/09/17"
```

```
as.Date("2021-11-03", format = "%Y-%m-%d") # %m for number month
## [1] "2021-11-03"
as.Date("2021-Nov-03", format = "%Y-%b-%d") # %b for the 3-letter month
## [1] "2021-11-03"
as.Date("03Nov2021", format = "%d%b%Y")
## [1] "2021-11-03"
```

Other functions from `lubridate`

```
library(lubridate)
# Change a date
x <- as.Date("2021-10-10")
month(x) <- 1
x
## [1] "2021-01-10"
```

```
# Set to the end of the month
day(x) <- days_in_month(x)
```

Business days

Use package `bizdays`

```
# install.packages("bizdays")
library(bizdays)
```

```
# 'weekends' is a calendar of weekdays
bizdays("2021-10-01", "2021-10-31", "weekends")
## [1] 20

# add bizdays
add.bizdays("2021-10-01", 5, "weekends")
## [1] "2021-10-08"

# Generate all business days between two dates.
# You will find this useful for financial application.
bizseq("2021-10-01", "2021-10-31", cal = "weekends")
##  [1] "2021-10-01" "2021-10-04" "2021-10-05" "2021-10-06" "2021-10-07"
##  [6] "2021-10-08" "2021-10-11" "2021-10-12" "2021-10-13" "2021-10-14"
## [11] "2021-10-15" "2021-10-18" "2021-10-19" "2021-10-20" "2021-10-21"
## [16] "2021-10-22" "2021-10-25" "2021-10-26" "2021-10-27" "2021-10-28"
## [21] "2021-10-29"
# bizdays excludes starting day, so one day less than bizseq.
length(bizseq("2021-10-01", "2021-10-31", cal = "weekends"))
## [1] 21
```

Calendar

If not provided, `start.date` is by default the first holiday and `end.date` is the last holiday, so we provide them here.

```
# Create a holiday calendar for this mini term.
create.calendar(name="MFE_Mini_2", holidays = c(as.Date("2021-10-28")),
                start.date = as.Date("2021-09-10"), end.date = as.Date("2021-10-31"),
                weekdays = c("saturday", "sunday"))

bizdays("2021-10-01", "2021-10-31", cal = "weekends")
## [1] 20
# One day less
bizdays("2021-10-01", "2021-10-31", cal = "MFE_Mini_2")
## [1] 19
```

Time

Convert time to character/string

- %H: hour
- %M: minute
- %S: second

```
format(Sys.time(), format = "%H%M")
## [1] "0147"
format(Sys.time(), format = "%H:%M:%S")
## [1] "01:47:05"
format(Sys.time(), format = "%H:%M:%S")
## [1] "01:47:05"
library(lubridate)
ymd_hms("2021-12-31 12:59:59")
## [1] "2021-12-31 12:59:59 UTC"
```

Time

Change time, lubridate provides `hour`, `minute`

```
x <- Sys.time()
x
## [1] "2020-09-17 01:47:05 +08"
hour(x) <- 12
x
## [1] "2020-09-17 12:47:05 +08"
minute(x) <- 3
x
## [1] "2020-09-17 12:03:05 +08"
minute(x) <- 123 # what will happen?
x
## [1] "2020-09-17 14:03:05 +08"
```

List - Basic

```
# Create a list with list() function
# Nameless list
# list[_n_] => item by order
a <- list(3, 4)
a[[1]]
## [1] 3
a[[2]]
## [1] 4

# Named list, you can use $ and [ operators
# list[[]]: gives back a value
# list$name => list[["name"]]
a <- list(a = 3, b = 4)
a[[1]]
## [1] 3
a[[2]]
## [1] 4
a[["a"]]
## [1] 3
a$a
## [1] 3
```

List - Create

```
# When you want to use a number as key, use backtick
list_of_strikes <- list()
list_of_strikes$`65` <- 3
list_of_strikes$`60` <- 4

# if a name doesn't exist in the list
a$c
## NULL
# Use `is.null()` to check
if (is.null(a$c)) {
  cat("c doesn't exist in list a\n")
}
## c doesn't exist in list a
```

List - Create

```
ll <- list(elem = 1, c1 = "a", c2 = "b")

# access the list
ll[[1]]
ll$elem
```

```
# add new member to the list
ll$new_elem <- 3
# update member in the list
ll$c1 <- 3

# set c1 to NULL would delete c1 from the list
ll$c1 <- NULL

ll
## $elem
## [1] 1
##
## $c2
## [1] "b"
##
## $new_elem
## [1] 3
```

List - Usage 1

```
# List - Basic
# Map
basket <- sample(c("Apple", "Orange", "Pear"), 100, replace = TRUE)
fruit_count <- list()
for (b in basket) {
  if (is.null(fruit_count[[b]])) {
    fruit_count[[b]] <- 1
  } else {
    fruit_count[[b]] <- fruit_count[[b]] + 1
  }
}
fruit_count
## $Pear
## [1] 37
##
## $Orange
## [1] 32
##
## $Apple
## [1] 31
```

List - Usage 2

```
# Let's write a generic function to do this
add_to_map <- function(map, key, value) {
  if (is.null(map[[key]])) {
    map[[key]] <- value
  } else {
    map[[key]] <- map[[key]] + value
  }
  map
}

# You may copy function add_to_map to every file that you want to use this kind of d
fruit_count <- add_to_map(fruit_count, "Pomelo", 12)
fruit_count
## $Pear
## [1] 37
##
## $Orange
## [1] 32
##
## $Apple
## [1] 31
##
## $Pomelo
## [1] 12
```

List - Usage 3

```
# Use case 1: Use list to pass data in or out.
# pass in
do_lots_of_work <- function(lst) {
  lst$a + lst$b
}
# pass out
ret_lots_of_work <- function() {
  return(list(a = a, b = b))
}

res <- ret_lots_of_work()
res$a
## $a
## [1] 3
##
## $b
## [1] 4
res$b
## [1] "Pear"
```

List - Usage 4

```
# Case 2: configuration
app_config <- list(MAX = 10, MIN = 10, DISPLAY_RESULT = TRUE)

do_lots_of_work <- function(app_config) {
  app_config$MAX
}
```

R: data frame

Common functions for data frame

```
View()
head()
tail()
str()
nrow()
ncol()
dim() # returns both nrow and ncol
colnames()/rownames()
```

R: data frame

The basic structure of a data frame:

- There is one observation per row and
- Each column represents a variable, a measure, feature, or characteristic of that observation.
- In summary, **2D table**

```
df <- tibble(
  date = seq(as.Date("2021-01-01"), as.Date("2021-01-10"), by = "day"),
  stock = replicate(10, paste0(sample(LETTERS, 3, replace = TRUE), collapse = "")),
  quantity = round(runif(10) * 10000 ,0))
# df["date"]: gives a data frame
# df[["date"]]: gives value
# df$date: same as [["date"]]

# Get three rows
df[c(3, 6, 9), , drop = F]
```

Data frame extraction with `drop = TRUE` or `drop = FALSE`

```
# Get three columns
df[, 1, drop = FALSE]
# This would return a vector
df[, 1, drop = TRUE]

# Use column names
df[, c("date", "quantity"), drop = FALSE]
```

Functions

Input parameters

```
func1 <- function() { }

func2 <- function(input1, input2) { }

# Param input1 is default to 1
func3 <- function(input1 = 1, input2) { }

func4 <- function(input1, input_type = c("int", "char")) {
  # This would check whether input_type is set to one of the pre-set values.
  input_type = match.arg(input_type)
}

func5 <- function(in1, in2) {
  if (in1 < 0) {
    return(0)
  } else {
    return(in1 + in2)
  }
}
```

Functions

```
# The last value before function finishes will be returned automatically.
# No need to use return.
func5 <- function(in1, in2) {
  if (in1 < 0) {
    0          # return this
  } else {
    in1 + in2 # or, return this
  }
}

# Unless there is extra steps before
func6 <- function(in1, in2) {
  if (in1 < 0) {
    return(0) # explicit-force return.
  } else {
    res <- in1 + in2
  }

  res <- res * 3
  res # res is the last value to be returned.
}
```

Anonymous Function

```
# Function that's defined in-place, which doesnt' need to have a name.
(function(x) { print(x) }) (3)
## [1] 3
# if there is only one line, you can skip { }
(function(x) print(x)) (3)
## [1] 3

# For longer functions, you can make it multi-lines.
(function(x) {
  if (x > 3) {
    print(x)
  } else {
    print(x - 3)
  }
})(3)
## [1] 0
```

purrr::map and sapply() Function - 1

```
library(purrr) # if not installed, run this line: install.packages("purrr").

# These two are equivalent.
res1 <- purrr::map(1:10, function(x) { rnorm(x, n = 10) })
# function(x) func(x) can be simplied as func.
res2 <- purrr::map(1:10, rnorm, n = 10)
head(res1, n = 1)
## [[1]]
##  [1]  1.824955643  1.384339487  1.028139356  1.739618010  0.135943228
##  [6]  2.150535246 -0.018378860  1.732545165  1.166419950  0.009825557
# purrr:map returns a list()
```

purrr::map and sapply() Function - 2

```
# This is what we really want to do.
# Generate ten normal distribution and get their mean.
# rnorm(n, mean = 0, sd = 1). Where does the input go to?
res <- purrr::map(1:10, rnorm, n = 1000)
map_dbl(res, mean)
##  [1]  1.019905  2.048421  3.012500  3.967535  5.031277  5.985041  6.986432
##  [8]  7.981051  8.990855 10.091227

# sapply() achieves the same as purrr::map(), a bit slower.
# Package purrr succeeds original R base.
sapply(1:10, function(x) x ^ 2 )
##  [1]   1   4   9  16  25  36  49  64  81 100
sapply(1:10, function(x) `^` (x, 2) )
##  [1]   1   4   9  16  25  36  49  64  81 100
sapply(1:10, function(x) `^` (2, x) )
##  [1]    2    4    8   16   32   64  128  256  512 1024
```

Exercise

Write functions to do

- Determine leap year?
- Print the list of month names in abbreviation or full
- Write a function to count how many working days in a year, given 1) the year 2) list of holidays?