Quality assurance/quality control (QA/QC) of the health data

Presenter: Dr. Ming-Chien Mark Tsou

Research Center for Environmental Changes

Academia Sinica

Outline

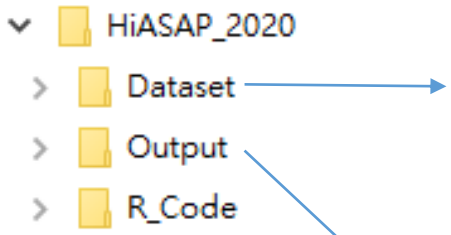
Part 1: Introduction of datasets

Part 2: Introduction of RStudio

Part 3: QA/QC of heart rate variability (HRV) data

Part 1:
Introduction of dataset

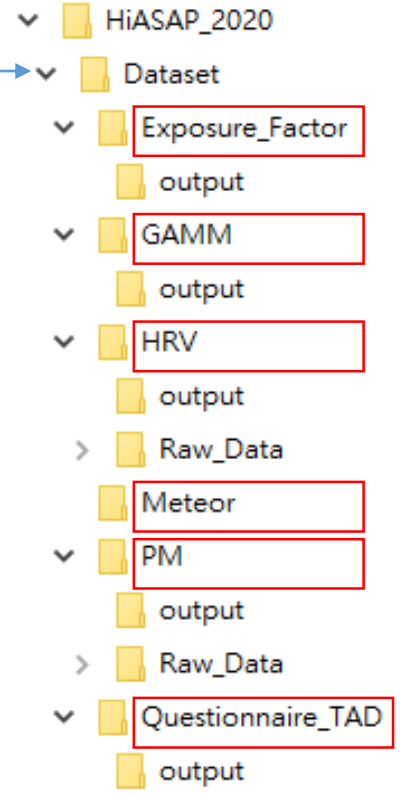
Datasets



1. The “Dataset” folder including PM, health (heart rate variability), questionnaire, time activity diaries and meteorological data

2. The “Output” folder including the all outputs which will generate in this training course

3. The “R_Code” folder



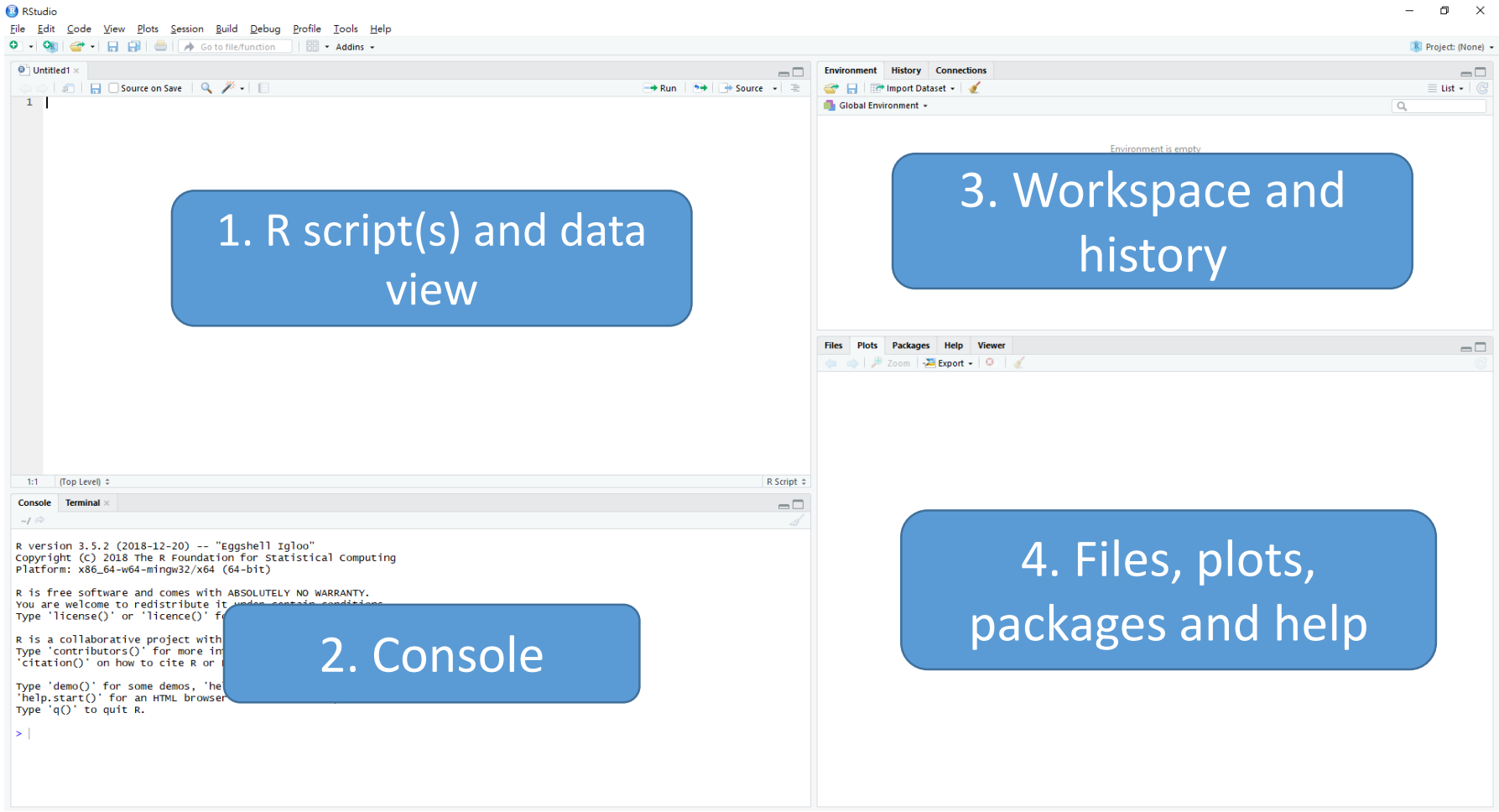
The datasets including 6 main sub-folders:

1. Exposure factors
2. GAMM (Generalized Additive Mixed Model)
3. HRV (heart rate variability) data
4. Meteorological data
5. PM data
6. Questionnaire and time-activity diary data

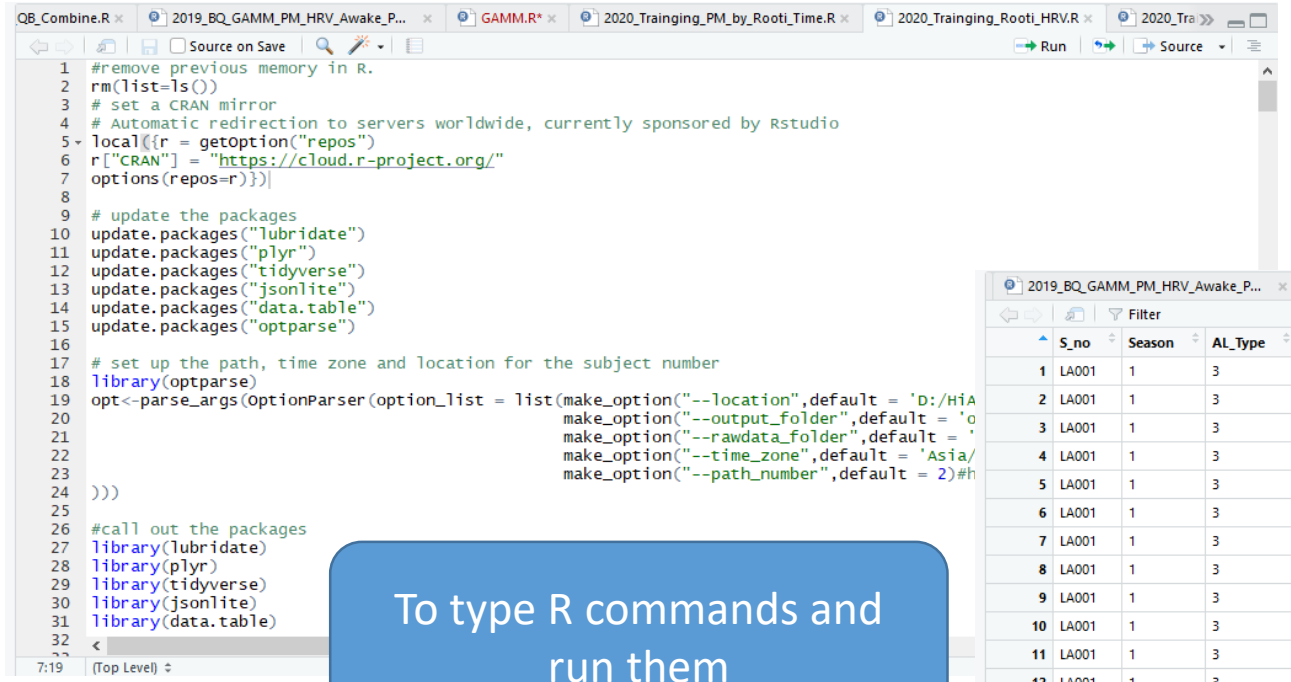
Part 2:
Introduction of RStudio

RStudio environments

- RStudio allows the user to run R in a more user-friendly environment.



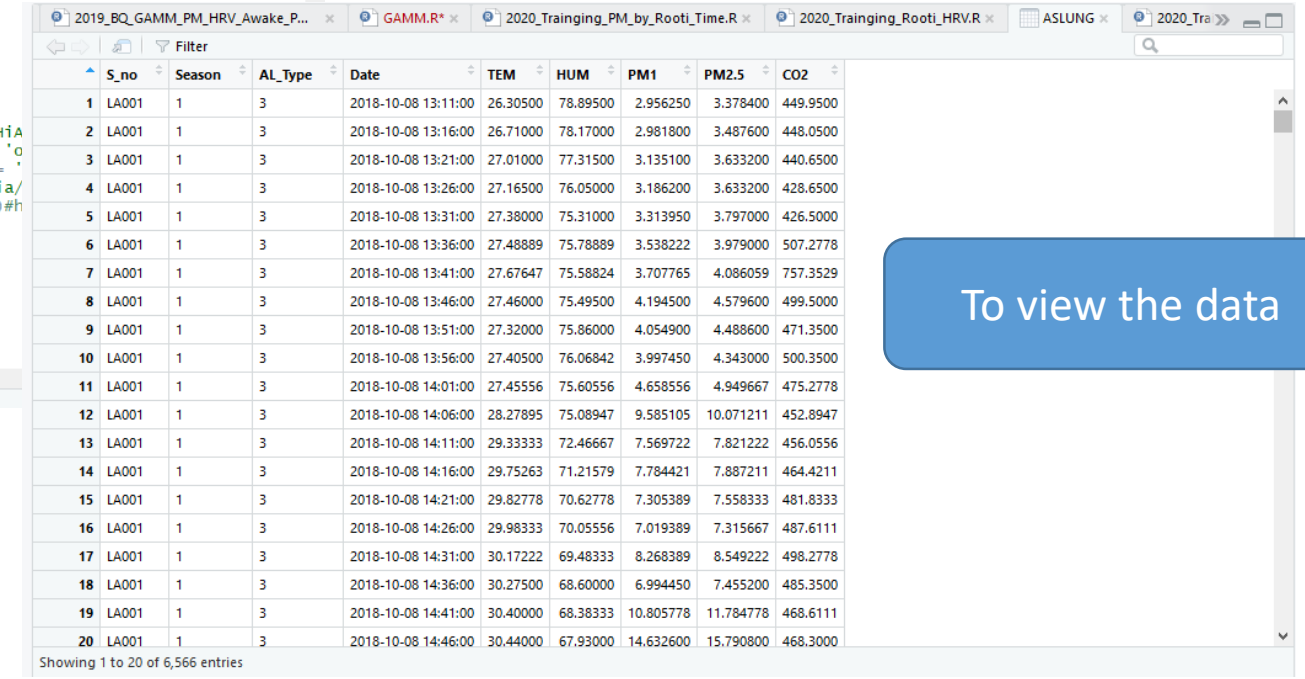
1. R script(s) and data view (upper left window)



The script can be saved as a R file

To type R commands and run them

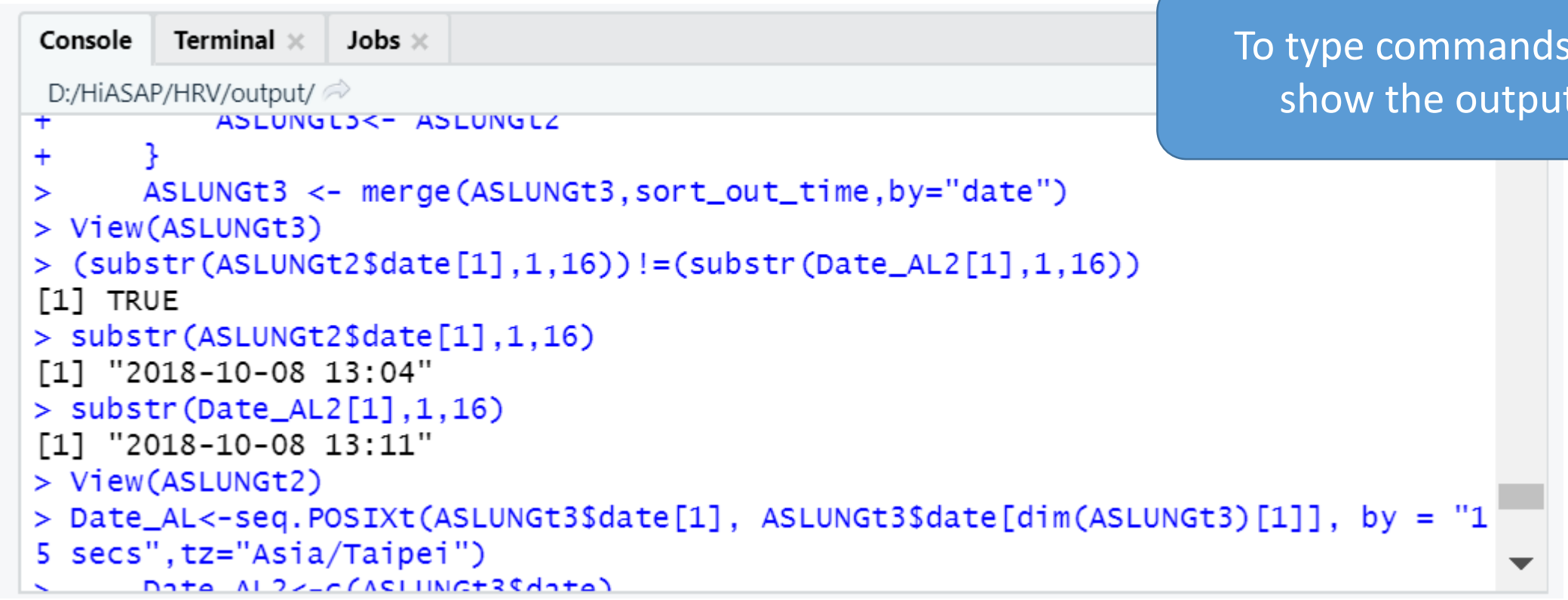
Output will appear in the Console window below.



	S_no	Season	AL_Type	Date	TEM	HUM	PM1	PM2.5	CO2
1	LA001	1	3	2018-10-08 13:11:00	26.30500	78.89500	2.956250	3.378400	449.9500
2	LA001	1	3	2018-10-08 13:16:00	26.71000	78.17000	2.981800	3.487600	448.0500
3	LA001	1	3	2018-10-08 13:21:00	27.01000	77.31500	3.135100	3.633200	440.6500
4	LA001	1	3	2018-10-08 13:26:00	27.16500	76.05000	3.186200	3.633200	428.6500
5	LA001	1	3	2018-10-08 13:31:00	27.38000	75.31000	3.313950	3.797000	426.5000
6	LA001	1	3	2018-10-08 13:36:00	27.48889	75.78889	3.538222	3.979000	507.2778
7	LA001	1	3	2018-10-08 13:41:00	27.67647	75.58824	3.707765	4.086059	757.3529
8	LA001	1	3	2018-10-08 13:46:00	27.46000	75.49500	4.194500	4.579600	499.5000
9	LA001	1	3	2018-10-08 13:51:00	27.32000	75.86000	4.054900	4.488600	471.3500
10	LA001	1	3	2018-10-08 13:56:00	27.40500	76.06842	3.997450	4.343000	500.3500
11	LA001	1	3	2018-10-08 14:01:00	27.45556	75.60556	4.658556	4.949667	475.2778
12	LA001	1	3	2018-10-08 14:06:00	28.27895	75.08947	9.585105	10.071211	452.8947
13	LA001	1	3	2018-10-08 14:11:00	29.33333	72.46667	7.569722	7.821222	456.0556
14	LA001	1	3	2018-10-08 14:16:00	29.75263	71.21579	7.784421	7.887211	464.4211
15	LA001	1	3	2018-10-08 14:21:00	29.82778	70.62778	7.305389	7.558333	481.8333
16	LA001	1	3	2018-10-08 14:26:00	29.98333	70.05556	7.019389	7.315667	487.6111
17	LA001	1	3	2018-10-08 14:31:00	30.17222	69.48333	8.268389	8.549222	498.2778
18	LA001	1	3	2018-10-08 14:36:00	30.27500	68.60000	6.994450	7.455200	485.3500
19	LA001	1	3	2018-10-08 14:41:00	30.40000	68.38333	10.805778	11.784778	468.6111
20	LA001	1	3	2018-10-08 14:46:00	30.44000	67.93000	14.632600	15.790800	468.3000

To view the data

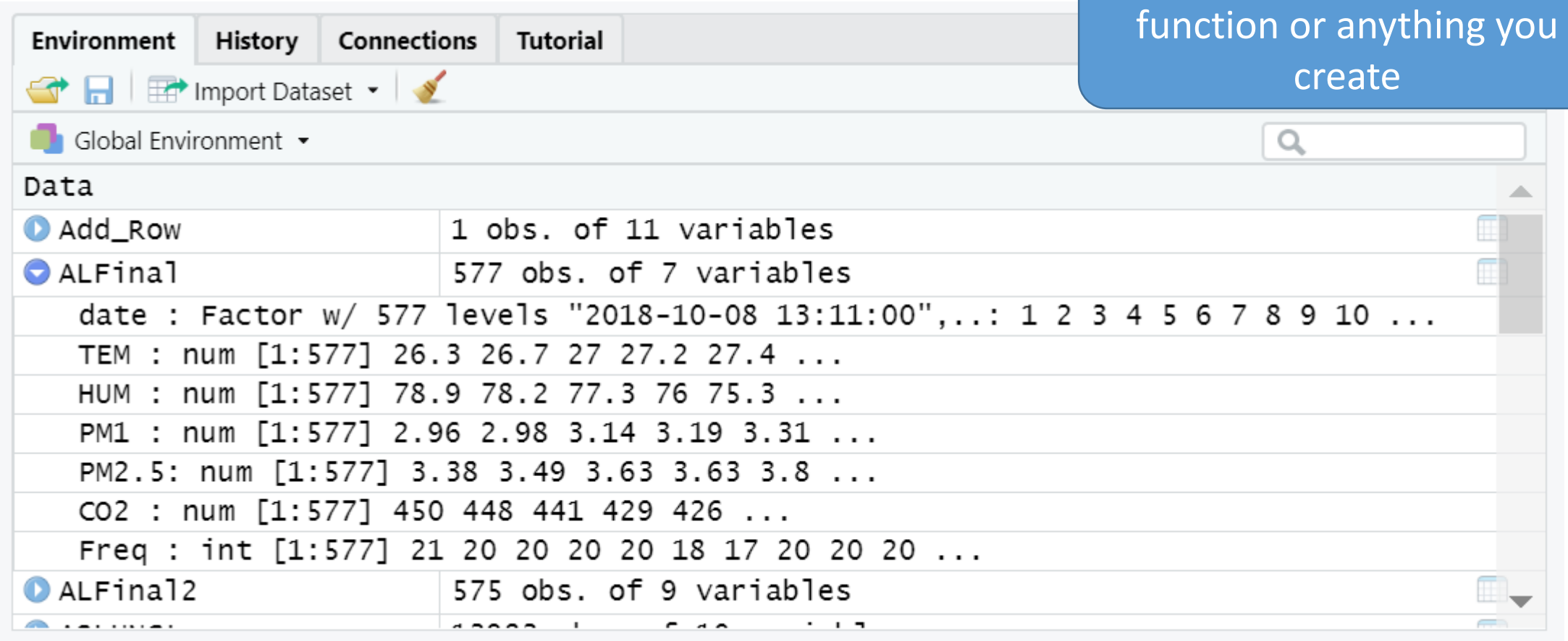
2. Console



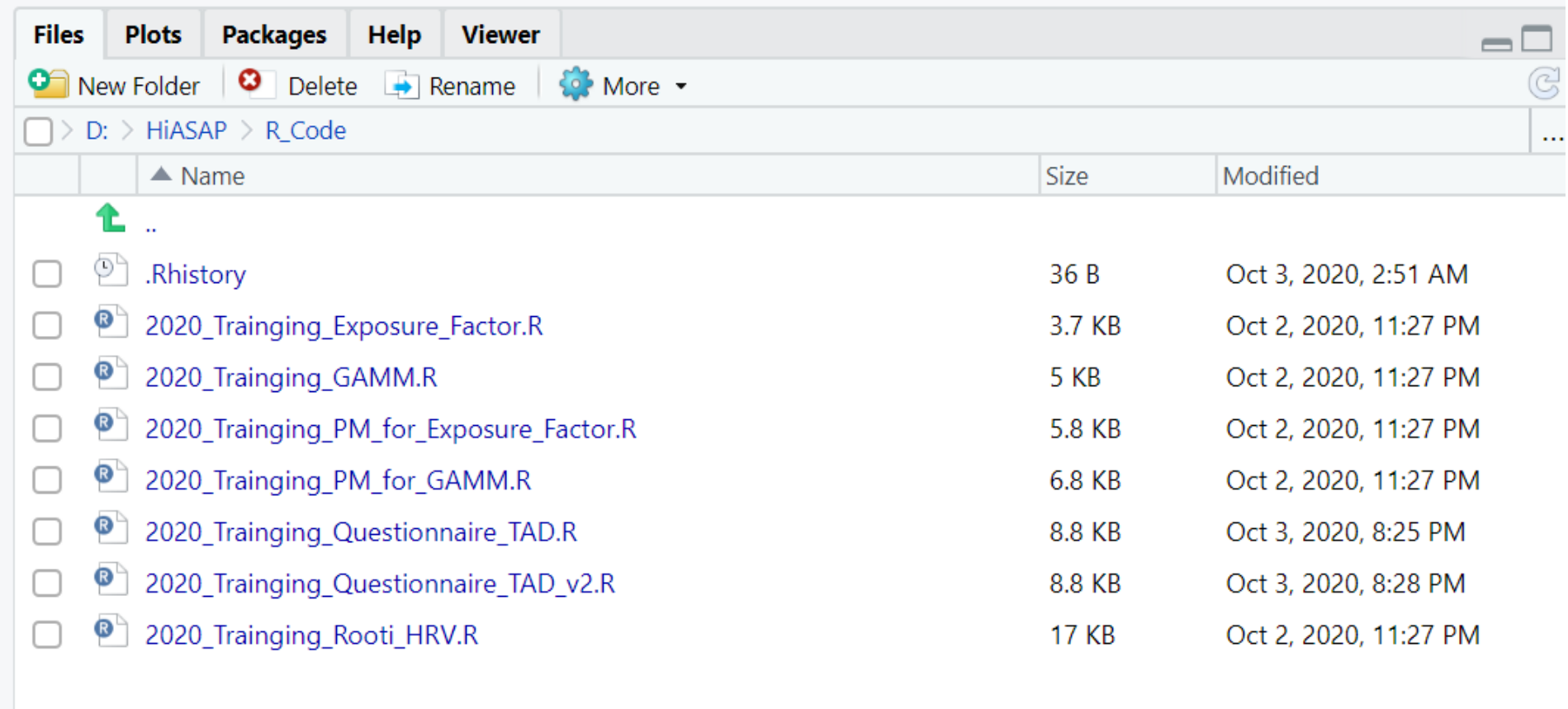
To type commands and show the outputs

3. Workspace

To store any object, value, function or anything you create



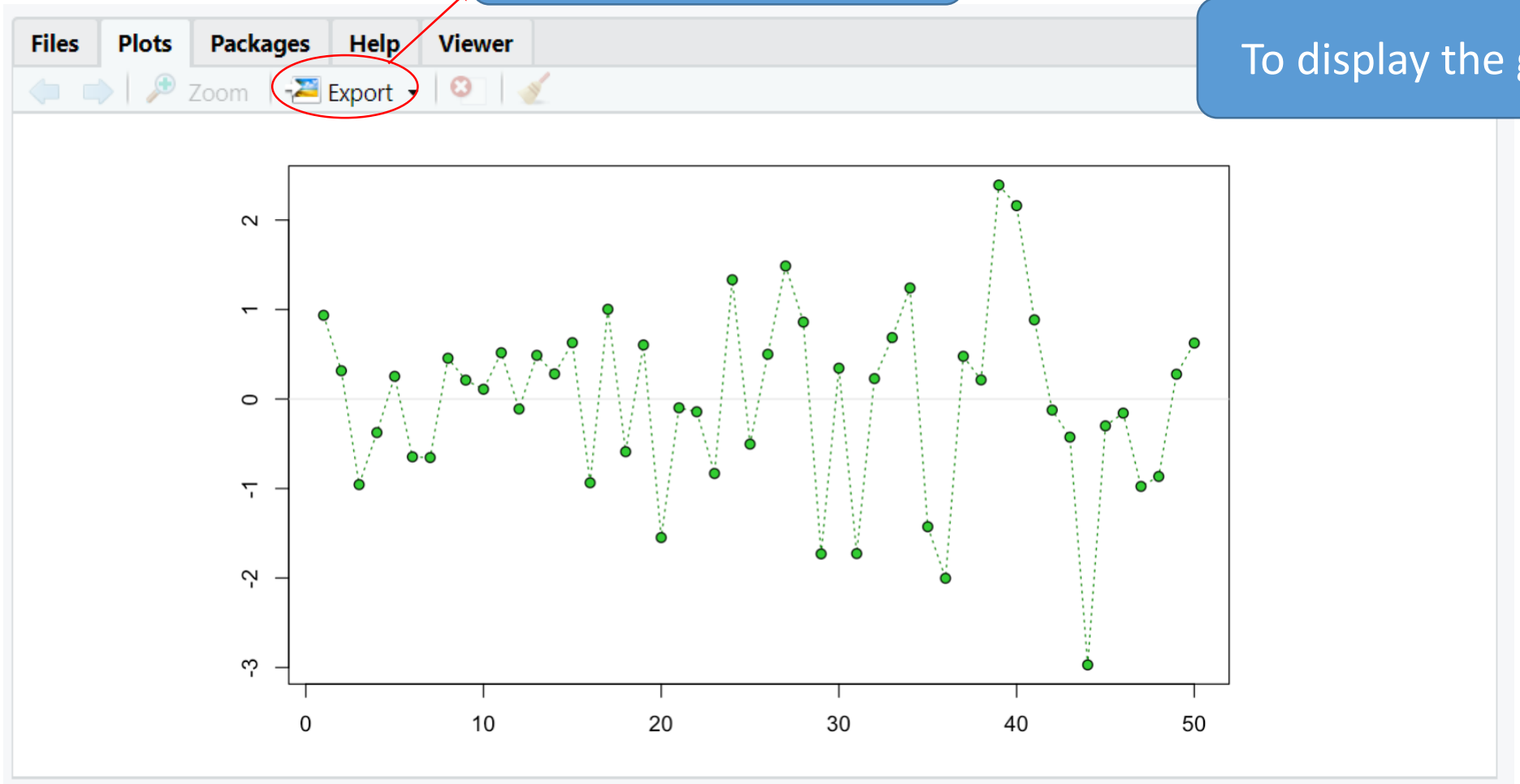
4. Files, plots, packages and help
- Files tab



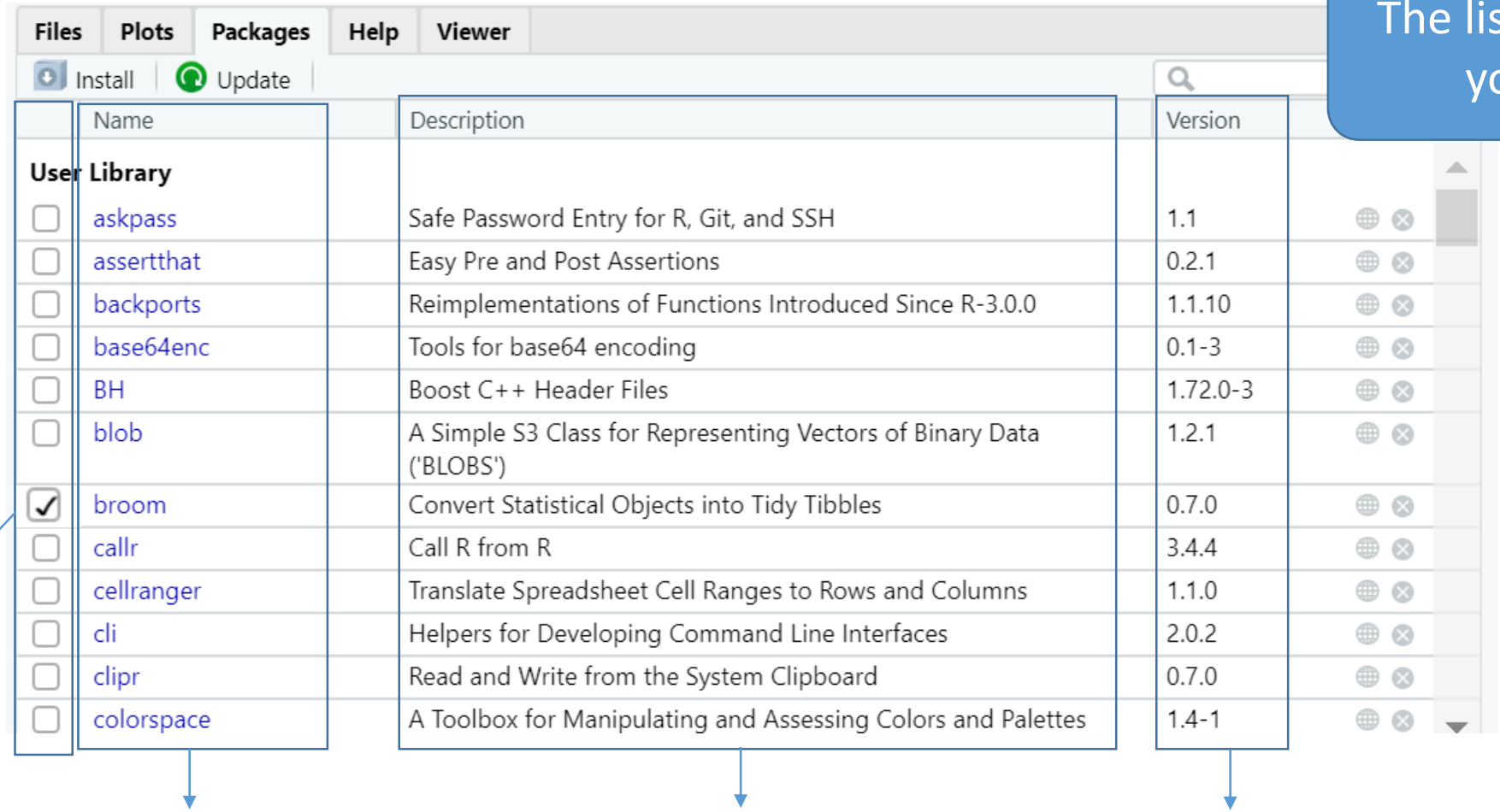
4. Files, plots, packages and help
- Plots tab

To export the graphs

To display the graphs



4. Files, plots, packages and help - Packages tab



The list of R packages you installed

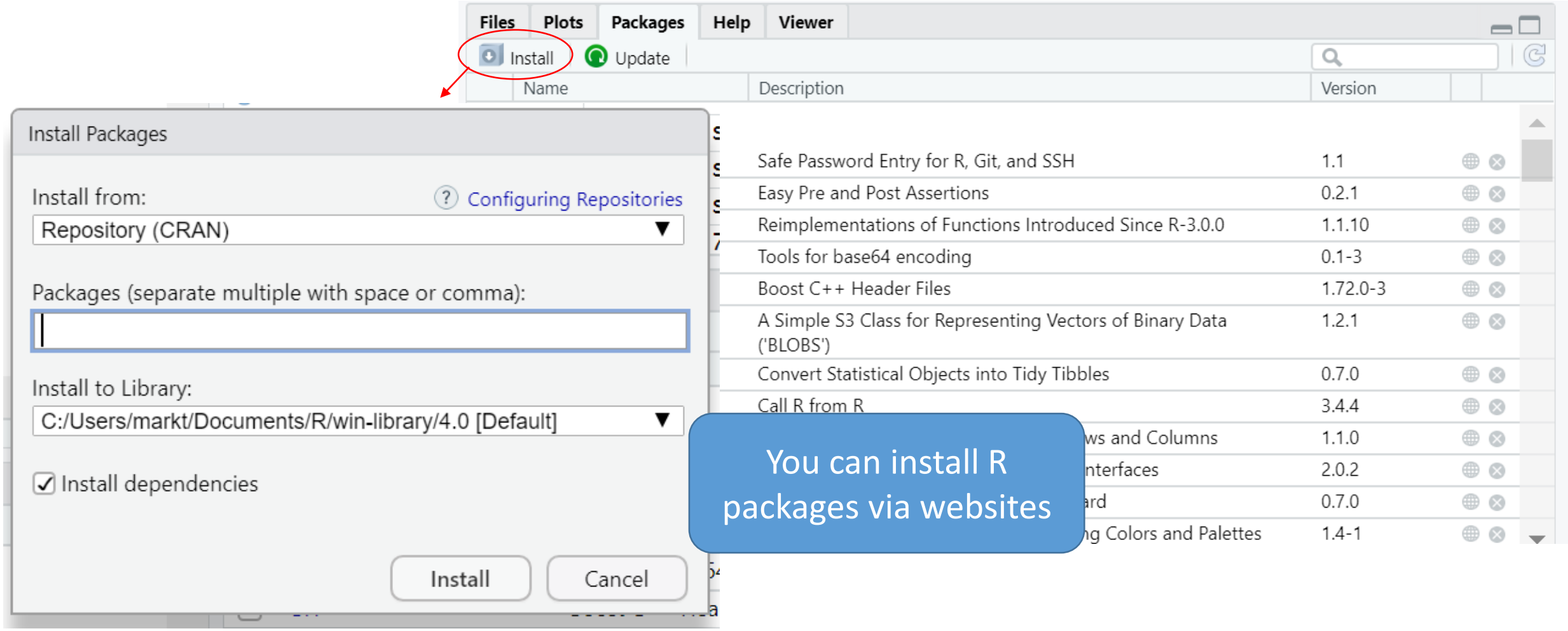
The tick means the R package has been loaded

The name of R packages

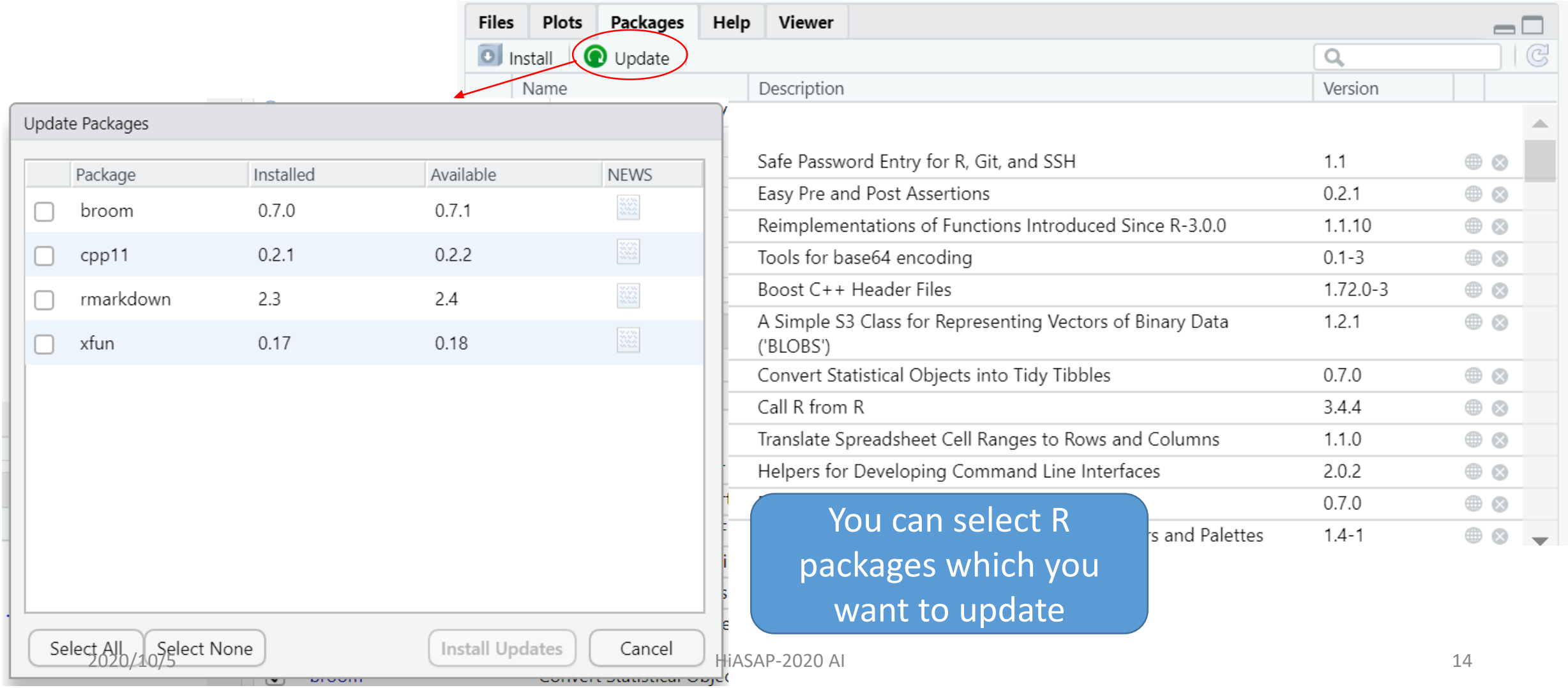
The description of R packages

The version of R packages

4. Files, plots, packages and help
- Packages tab

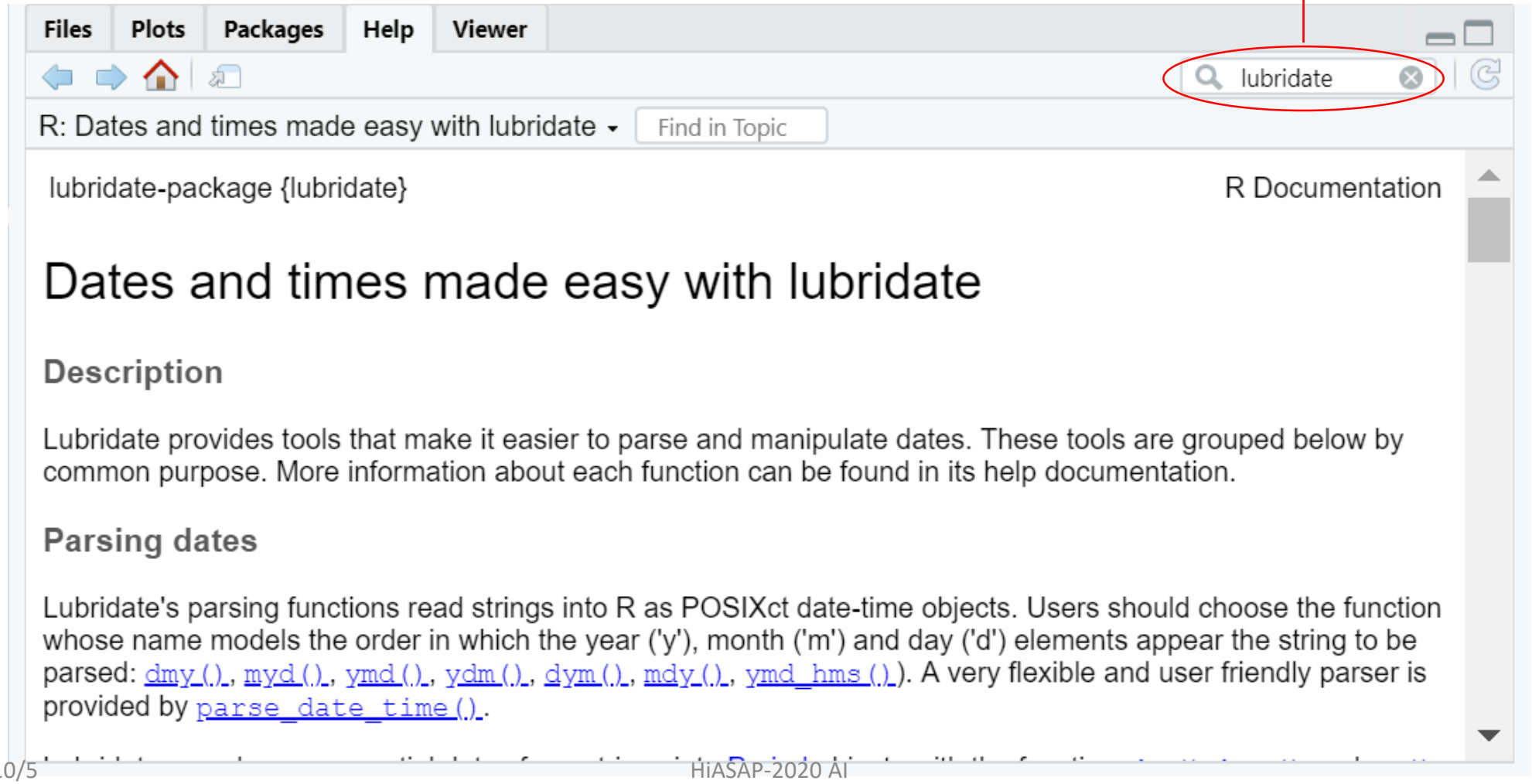


4. Files, plots, packages and help - Packages tab

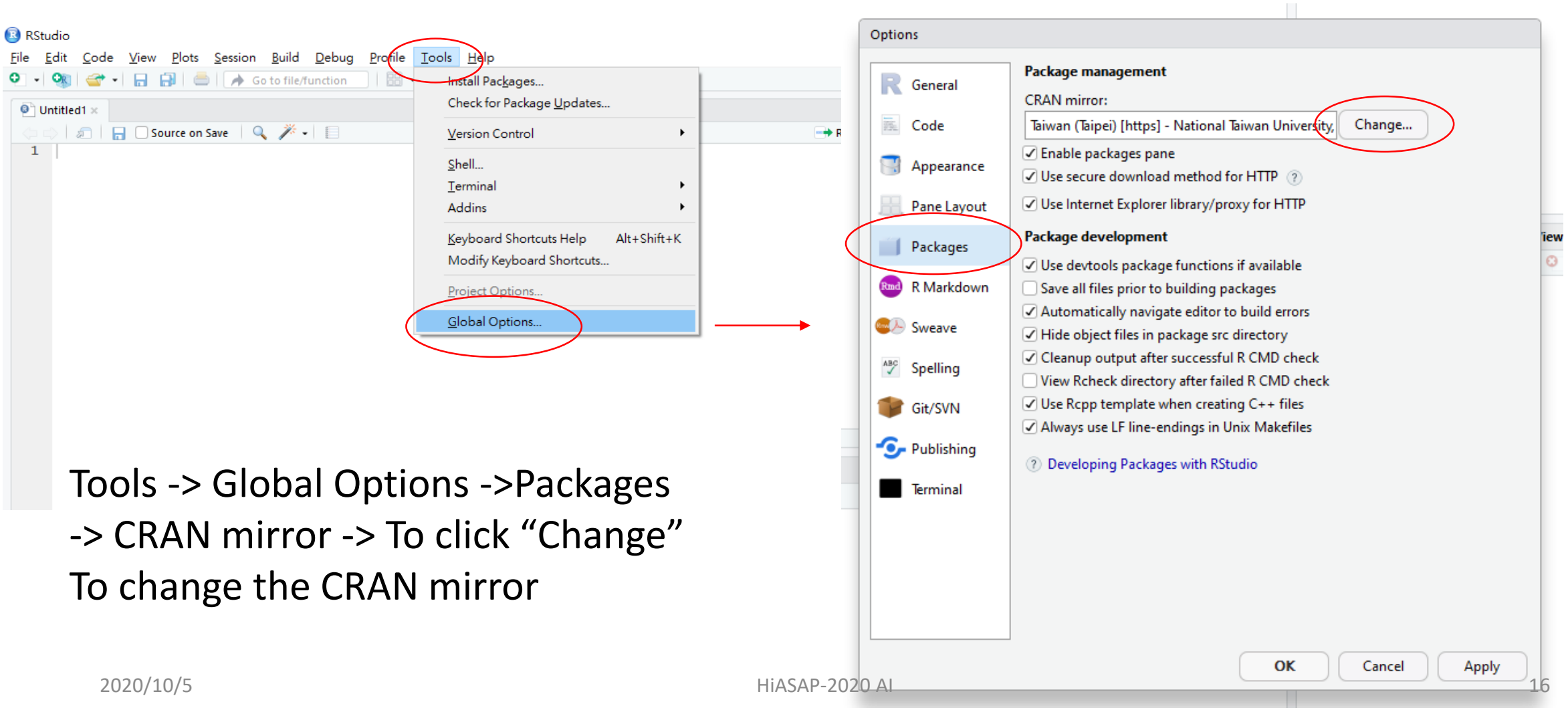


4. Files, plots, packages and help - Help tab

You can search the documents of R packages



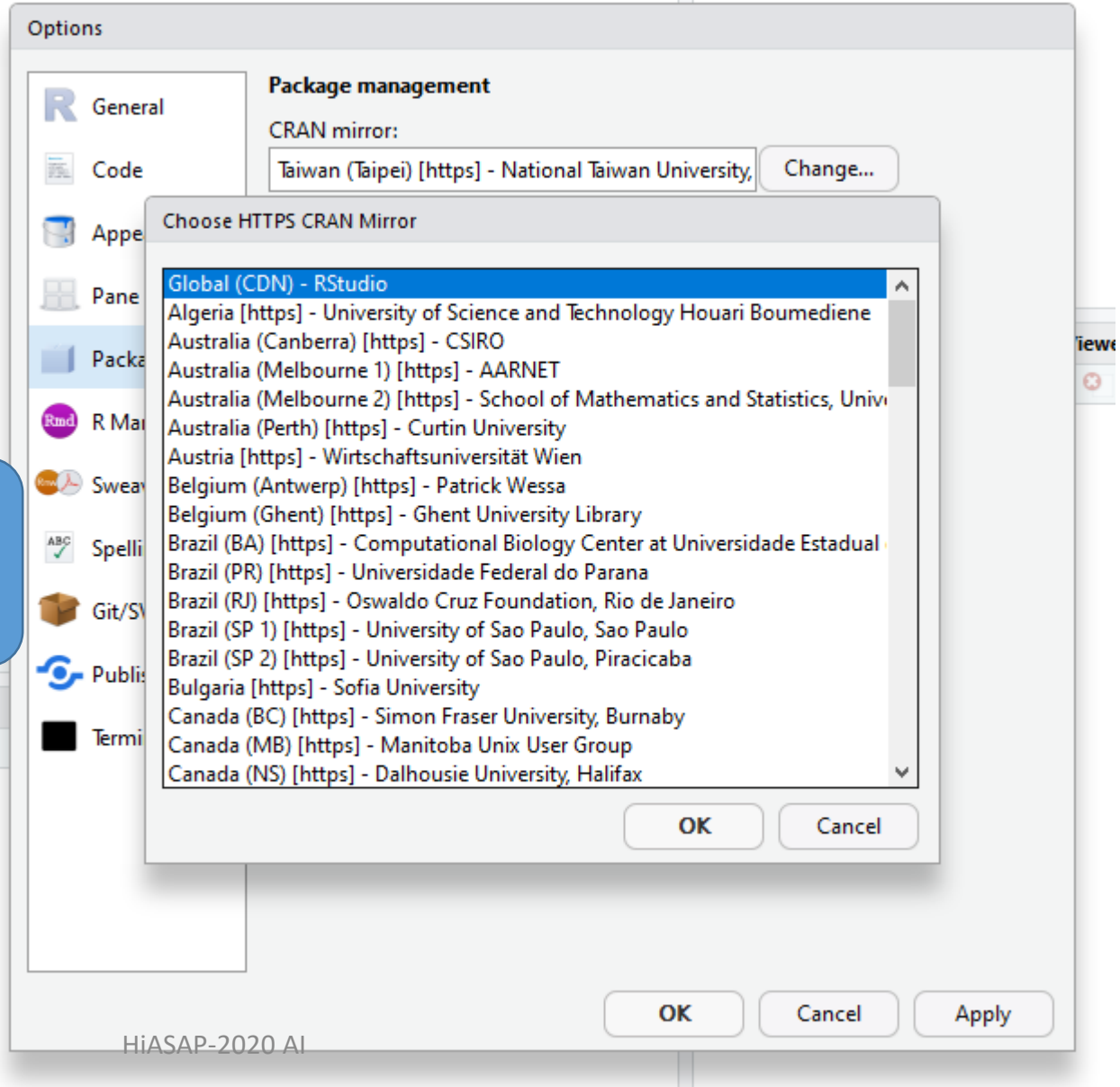
To set the CRAN mirror to download/update the R packages



Tools -> Global Options ->Packages
-> CRAN mirror -> To click “Change”
To change the CRAN mirror

To set the CRAN mirror to download/update the R packages

TO choose the CRAN mirror nearest to you to minimize network load



Part 3:
QA/QC of HRV data

Notices

- All text after the pound sign "#" within the same line in R code
  - To be considered a comment
  - To be not run by R

- In this presentation, the R codes in the red box can be modify according your requirements (mostly the path of data file)
  - For example, you can modify the path of output file by yourself

```
# To set the output file
cmd1 <- paste0("setwd('",location,"HiASAP/PM/output')")
eval(parse(text=cmd1))
```

Notices

- To use quotes (“) to tell R to interpret something as a string.
  - For example,

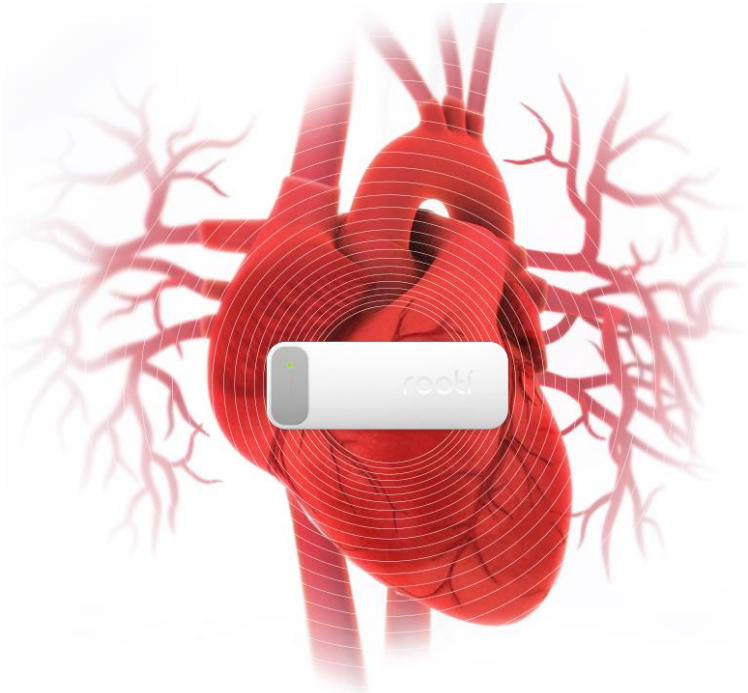
```
location <- "D:/"
```

→ D:/

- The uppercase letters (strings) are different from the lowercase letters (strings)
  - For example,
  - A ≠ a
  - Apple ≠ apple

What kind of data we can get from Rooti

- Standard deviation of all normal to normal intervals (SDNN)
- Square root of the mean of the sum of the squares of differences between adjacent NN intervals (RMSSD)
- LF (low frequency power)
- HF (high frequency power)
- VLF (very low frequency power)
- TP (total power)
- HF/LF ratio
- HR (heart rate)
- Activity data
- Sleep index

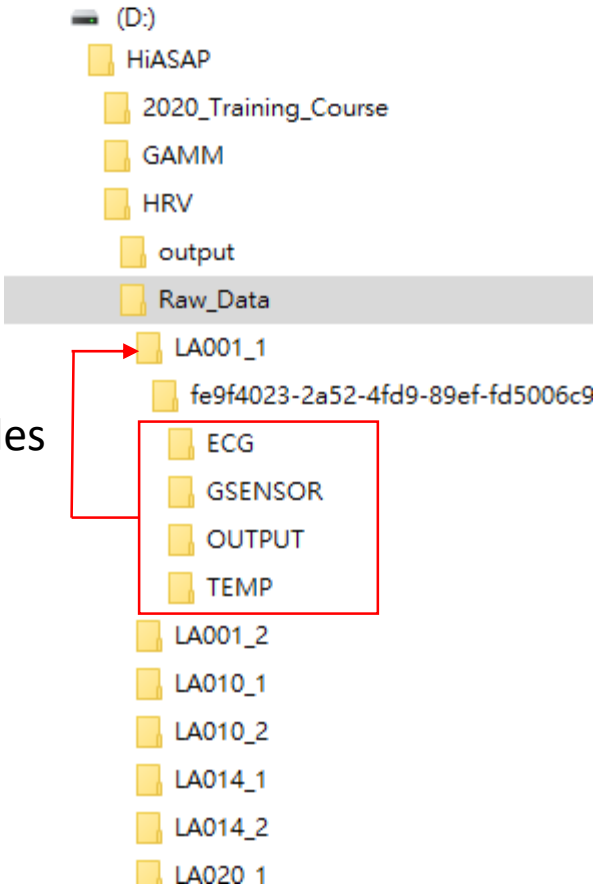


RootiRx sensor

Source: https://www.rootilabs.com/

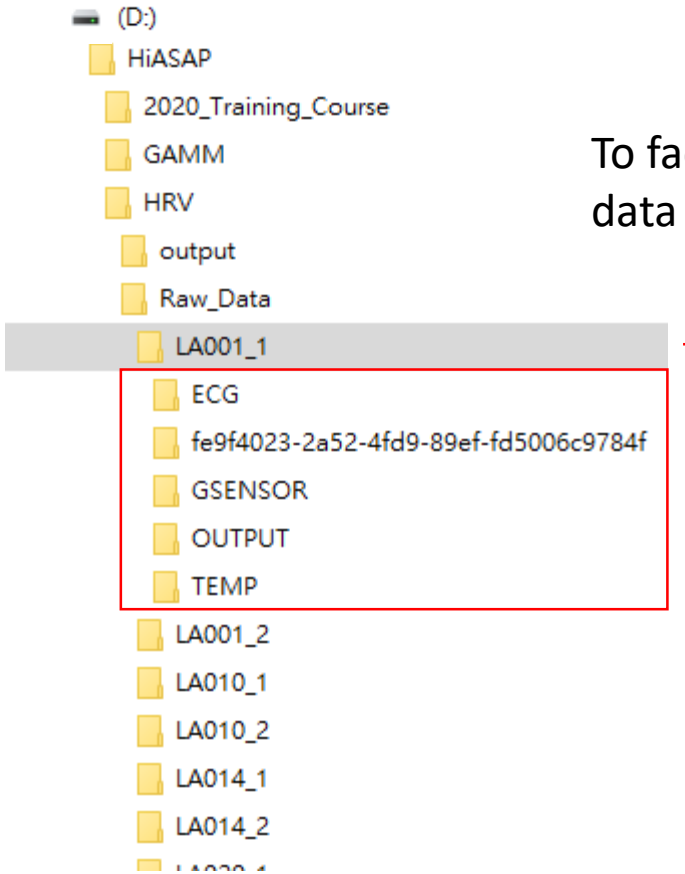
Moving all data files to its own file for every subject

Before



Moving files

After



To facilitate to read data during analysis

```r
# To remove previous memory in R.
rm(list=ls())

# To update the R packages
update.packages("lubridate")
update.packages("plyr")
update.packages("tidyverse")
update.packages("jsonlite")
update.packages("data.table")

# To load the R packages
library(lubridate)
library(plyr)
library(tidyverse)
library(jsonlite)
library(data.table)
```

1. To remove all objects from current workspace

2. To update the R packages

3. To load the R packages

You can modify by yourself

```
18  location <- "D:/"
19
20  # To set the output file
21  cmd1 <- paste0("setwd('",location,'HiASAP/HRV/output')")
22  eval(parse(text=cmd1))
```

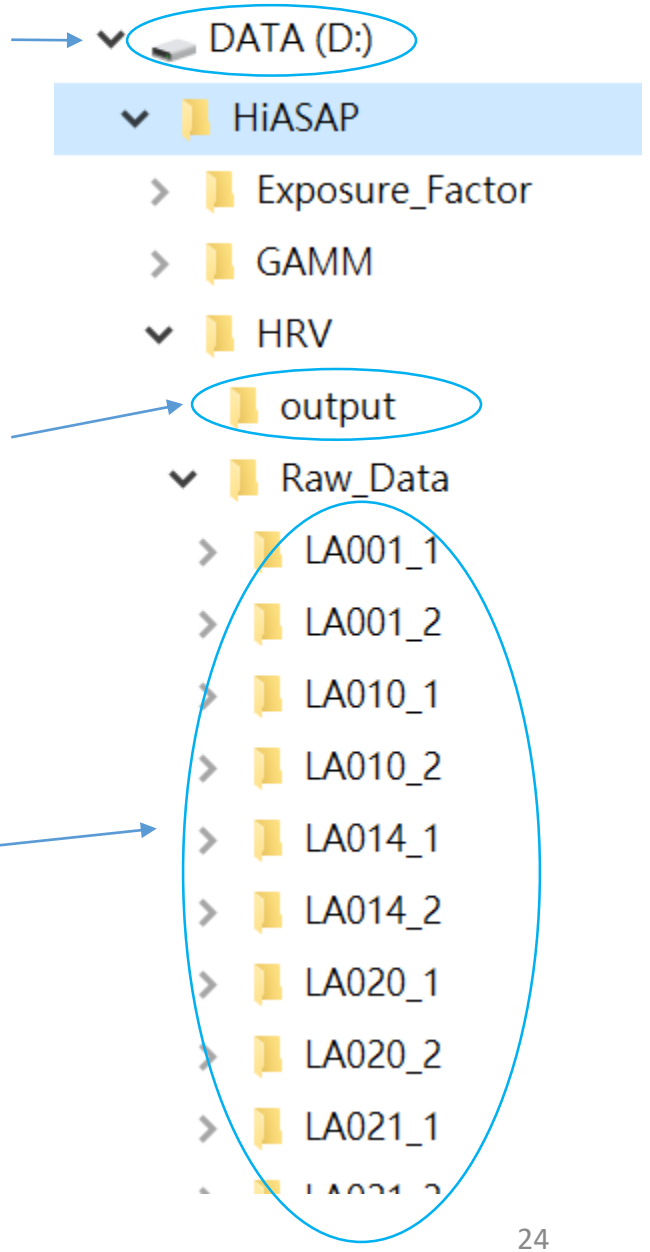
4. To set the default drive of your data

5. To set the path of output file

6. To set the path of HRV data

```
24  # To set the raw data file
25  way <- paste0(location,'HiASAP/HRV/Raw_Data/')
26  # To set the ID list
27  subject<-dir(path=way, pattern="LA")
```

To set the pattern (keyword) to select files



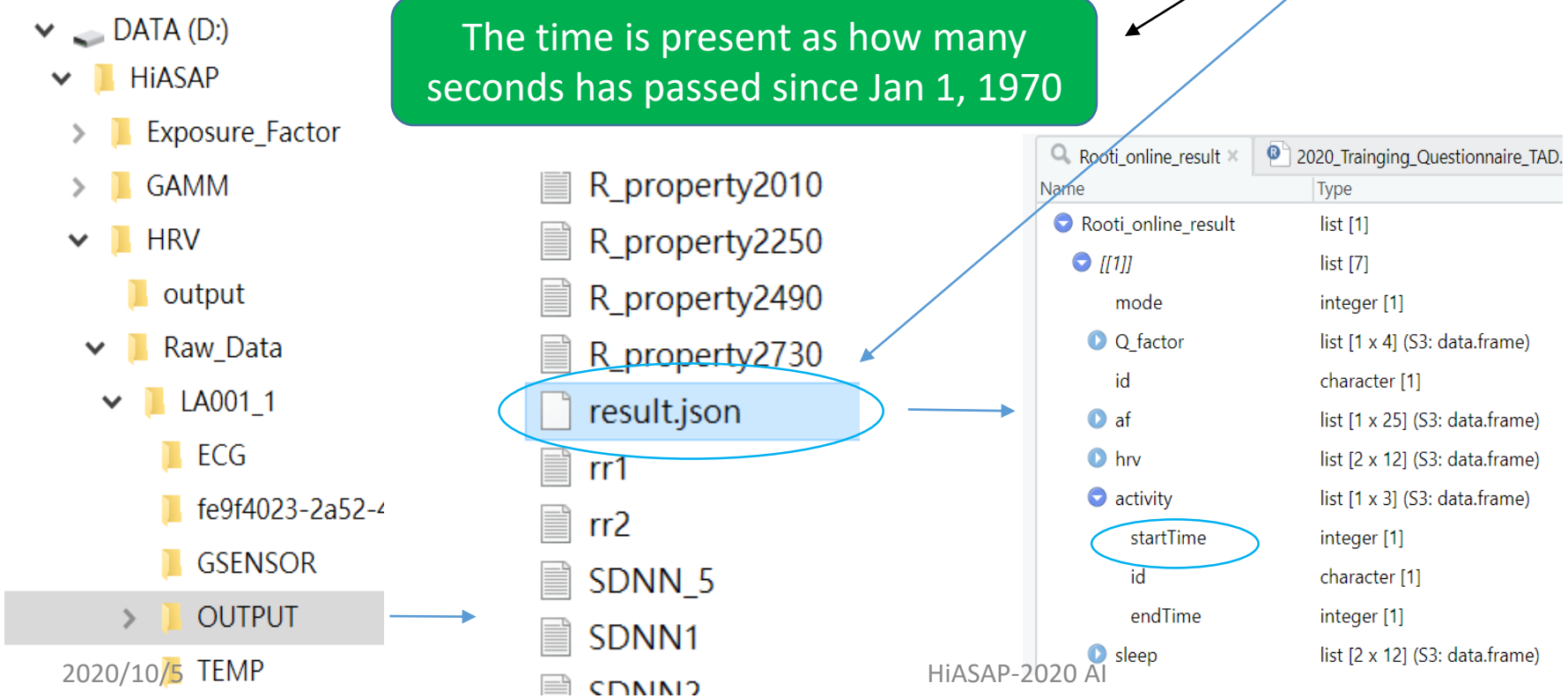
7. To read the results of HRV monitoring for getting the start time

→ You can modify by yourself

```
29 for (i in 1) {
30       # To read the "result.json" file for getting the start time of Rooti (heart rate variability monitoring)
31       Rooti_online_result<-list()
32       Rooti_online_result[[i]]<- fromJSON(paste0(way, subject[i], "/OUTPUT/result.json"))
33       start_time<-list()
34       start_time[[i]]<-Rooti_online_result[[i]]$activity$startTime
35       start_time[[i]]<-as.POSIXct(start_time[[i]], origin="1970-01-01",tz="Asia/Taipei")
```

The time is present as how many seconds has passed since Jan 1, 1970

The code of time zone



More detailed information about the code of time zone can be found in the following website: https://data.iana.org/time-zones/theory.html

Extracting the HRV data

From line 37 to 211, we extract the results of each HRV indices with the almost same procedure

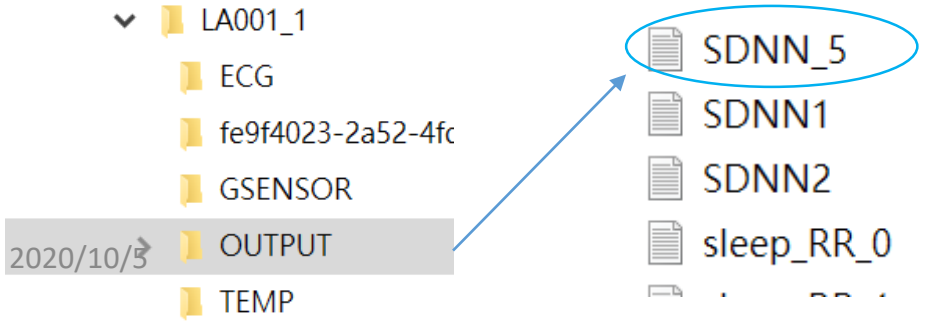
8. To read the results of 5-min SDNN

```
37      # To get the 5-min SDNN data
38      aa <- read.table(paste0(way, subject[i], "/OUTPUT/SDNN_5.txt"))
39      test<-substr(subject[i],1,5)
40      Rooti_SDNN5<-data.frame(test,aa)
41      colnames(Rooti_SDNN5)[names(Rooti_SDNN5) == "V1"]<-"SDNN5"
```

To add the variable of subjects' ID

9. To create the variable of data time

```
43      total_time<-minutes(dim(Rooti_SDNN5)[1]*5)
44      Datatime<-seq.POSIXt(start_time[[i]][1],start_time[[i]][1]+total_time , by ="5 mins")
45      Datatime<-Datatime[1:(length(Datatime)-1)]
46
47      Rooti_SDNN5<-data.frame(Datatime, subset(Rooti_SDNN5,select=c(test,SDNN5)))
```



10. To combine data time with SDNN data

Extracting the HRV data

11. To extract the 5-min RMSSD, LF/HF ratio, LF, HF, VLF and TP data

- From Line 49 to 85
- The same procedure as SDNN

```
49      # To get the 5-min RMSSD data
50      aa <- read.table(paste0(way, subject[i], "/OUTPUT/RMSSD_5.txt"))
51      test<-substr(subject[i],1,5)
52      Rooti_RMSSD5<-data.frame(test,aa)
53      colnames(Rooti_RMSSD5)[names(Rooti_RMSSD5) == "V1"]<-"RMSSD5"
54
55      Rooti_RMSSD5<-data.frame(Datatime, subset(Rooti_RMSSD5,select=c(test,RMSSD5)))
56
57      # To get the 5-min LF/HF data
58      aa
59      te
60      Ro
61      co
62
63      #
64      aa
65      te
66      Ro
67      co
```

```
69          # To get the 5-min HF data
70          aa <- read.table(paste0(way, subject[i], "/OUTPUT/hf_5.txt"))
71          test<-substr(subject[i],1,5)
72          Rooti_hf5<-data.frame(test,aa)
73          colnames(Rooti_hf5)[names(Rooti_hf5) == "V1"]<-"HF5"
74
75          # To get the 5-min VLF data
76          aa <- read.table(paste0(way, subject[i], "/OUTPUT/vlf_5.txt"))
77          test<-substr(subject[i],1,5)
78          Rooti_vlf5<-data.frame(test,aa)
79          colnames(Rooti_vlf5)[names(Rooti_vlf5) == "V1"]<-"VLF5"
80
81          # To get the 5-min TP data
82          aa <- read.table(paste0(way, subject[i], "/OUTPUT/tp_5.txt"))
83          test<-substr(subject[i],1,5)
84          Rooti_tp5<-data.frame(test,aa)
85          colnames(Rooti_tp5)[names(Rooti_tp5) == "V1"]<-"TP5"
```

→ You can modify by yourself

Extracting the heart rate (HR) data

12. To read the 1-min HR data

13. To create the variable of data time

14. To calculate the sum and mean of HR data for 5-min intervals

```
87    # To get the 1-min HR data
88    aa <- read.table(paste0(way, subject[i], "/OUTPUT/HR_full.txt"))
89    test<-substr(subject[i],1,5)
90    Rooti_HR<-data.frame(test,aa)
91    colnames(Rooti_HR)[names(Rooti_HR) == "V1"]<-"HR"
92
93    # To calculate the 5-min HR dat
94    total_HR_time<-minutes(dim(Rooti_HR)[1]*1)
95    Datatime_HR<-seq.POSIXt(start_time[[i]][1],start_time[[i]][1]+total_HR_time , by ="1 mins")
96    Datatime_HR<-Datatime_HR[1:(length(Datatime_HR)-1)]
97
98    Rooti_HR<-data.frame(Datatime_HR, Rooti_HR)
99    Rooti_HR<-Rooti_HR %>%
100     group_by(Datatime = cut(Datatime_HR, breaks="300 secs")) %>%
101     summarize(
102       HRsum5 = sum(HR),
103       HRmean5 = floor(mean(HR)))
104   Rooti_HR$Datatime <-ymd_hms(Rooti_HR$Datatime,tz="Asia/Taipei")
```

You can modify by yourself

Extracting activity data (variations for three-axis)

- Activity data
  - Variations for X-, Y- and Z- axis
  - Accelerations for X-, Y- and Z- axis

15. To extract the 1-min activity data of variations for three-axis, and then calculate to 5-min average data

- From Line 106 to 122
- The same procedure as HR

```
106     # To get the activity data form G-sensor
107     # To get the 1-min data of variations for three-axis
108     aa <- read.table(paste0(way, subject[i], "/OUTPUT/Avg_XYZsum.txt"))
109     test<-substr(subject[i],1,5)
110     Rooti_gsensor<-data.frame(test,aa)
111     colnames(Rooti_gsensor)[names(Rooti_gsensor) == "V1"]<-"Gsensor"
112
113     # To calculate the 5-min data of variations for three-axis
114     total_gsensor_time<-minutes(dim(Rooti_gsensor)[1]*1)
115     Datatime_gsensor<-seq.POSIXt(start_time[[i]][1],start_time[[i]][1]+total_gsensor_time , by = "1 mins")
116     Datatime_gsensor<-Datatime_gsensor[1:(length(Datatime_gsensor)-1)]
117
118     Rooti_gsensor<-data.frame(Datatime_gsensor, Rooti_gsensor)
119     Rooti_gsensor<-Rooti_gsensor %>%
120       group_by(Datatime = cut(Datatime_gsensor, breaks="300 secs")) %>%
121       summarize(Gsensor5 = sum(Gsensor))
122     Rooti_gsensor$Datatime <-ymd_hms(Rooti_gsensor$Datatime,tz="Asia/Taipei")
```

→ You can modify by yourself

Extracting activity data (accelerations for three-axis)

```r
# To get the 1-min data of accelerations for three-axis
aa <- list.files(paste0(way, subject[i], "/GSENSOR/"))
bb <- read.table(paste0(way, subject[i], "/GSENSOR/",aa[1]),sep=",")
cc <- bb
for(j in 2:length(aa)){
    bb <- read.table(paste0(way, subject[i], "/GSENSOR/",aa[j]),sep=",")
    cc <- rbind(cc,bb)
}
test<-substr(subject[i],1,5)
Rooti_gsensor_raw_data<-data.frame(test,subset(cc,select=c(V1:V5)))
colnames(Rooti_gsensor_raw_data)<-c("S_no","Datatime","secondpoint", "X", "Y", "Z")
Rooti_gsensor_raw_data$Datatime<-as.POSIXct(Rooti_gsensor_raw_data$Datatime, origin="1970-01-01",tz="Asia/Taipei")
```

16. To extract the 1-min activity data of accelerations for three-axis

```r
# To get the 5-min data of accelerations for three-axis
Rooti_gsensor_raw_data<-Rooti_gsensor_raw_data %>%
  group_by(Datatime = cut(Datatime, breaks="300 secs")) %>%
  summarize(meanX5 = round(mean(X),4),
            meanY5 = round(mean(Y),4),
            meanZ5 = round(mean(Z),4),
            maxX5 = round(max(X),4),
            maxY5 = round(max(Y),4),
            maxZ5 = round(max(Z),4)
            ) %>%
  mutate(Datatime = ymd_hms(Datatime,tz="Asia/Taipei"))
```

17. To calculate the mean and maximum of accelerations for three-axis for 5-min intervals

Extracting activity data (accelerations for three-axis)

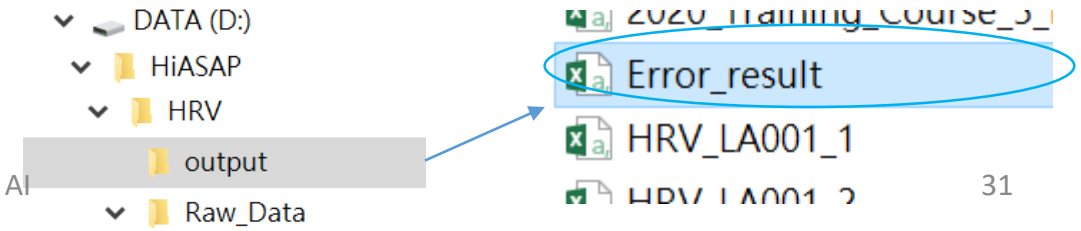
- Because the start time may be different between G-sensor and HRV monitoring (“result.json” file), the difference between two files should be less than 3 seconds.

18. To determine the difference of start time between G-sensor and “result.json” file

```
149
150  # To check whether the time of G-sensor is correct
151  gap_of_time <-seconds(Rooti_SDNN5$Datatime[1]-Rooti_gsensor_raw_data$Datatime[1])
152
153  if(abs(gap_of_time)<=3){
154  Rooti_gsensor_raw_data<-Rooti_gsensor_raw_data %>%
155    mutate(Datatime = Datatime +gap_of_time)
156  }else{
157    start_time_error_gsensor<-"Please check the start time of gsensor in GSENSOR folder and start time of activity in result.json."
158    write.csv(start_time_error_gsensor,paste0("Start_time_error_in ",subject[i],"_gsensor.csv"),row.names = F)
   }
```

If the difference is less than 3 seconds, the time will be corrected

If the difference is more than 3 seconds, the process will be terminated



You can modify by yourself

Extracting sleeping index

```
160  # To get the sleeping index
161  sleep_start_time<-list()
162  in_bed_time<-list()
163  sleep_idx<-list()
164  Datatime_sleep<-data.frame()
165  sleep_start_time[[i]]<-Rooti_online_result[[i]]$sleep$sleepStartTime
```

19. To get the start time of sleeping time

If subjects do not have sleeping data, it will not run the following code of sleeping index

```
166  if(!is.null(Rooti_online_result[[i]]$sleep$sleepStartTime)){
167  sleep_start_time[[i]]<-as.POSIXct(sleep_start_time[[i]], origin="1970-01-01",tz="Asia/Taipei")
168  in_bed_time[[i]]<-Rooti_online_result[[i]]$sleep$inBedTime
169  sleep_idx[[i]]<-Rooti_online_result[[i]]$sleep$slp_idx
```

20. To get the time and sleeping index during the sleeping period

Name	Type	Value
Rooti_online_result	list [7]	List of length
sleep	list [2 x 12] (S3: data.frame)	A data.frame
sleepStartTime	integer [2]	1539007015 1
WASO	integer [2]	80 26
SOL	integer [2]	38 58
inBedTime	integer [2]	601 633
slp_idx	list [2]	List of length

→ You can modify by yourself

Extracting sleeping index

21. To calculated the data time of the sleeping time

```
170     for (s in 1:length(sleep_start_time[[i]])) {
171     Datatime_sleep_m<-data.frame(Datatime =seq.POSIXt(sleep_start_time[[i]][s],
                        sleep_start_time[[i]][s]+minutes(in_bed_time[[i]][s]) , by = "1 mins"))
```

22. To combine the sleeping index with data time

```
172     Datatime_sleep_m<-Datatime_sleep_m[(2:nrow(Datatime_sleep_m)),]
173     sleep_idx[[i]][[s]]<-sleep_idx[[i]][[s]][(1:length(Datatime_sleep_m))]
174     Datatime_sleep_m<-data.frame(Datatime =Datatime_sleep_m,sleep_idx=sleep_idx[[i]][[s]])
175     Datatime_sleep<-rbind(Datatime_sleep_m,Datatime_sleep)
176     Datatime_sleep$Datatime<-as.POSIXct(Datatime_sleep$Datatime, origin="1970-01-01",tz="Asia/Taipei")
177     }
```

You can modify by yourself

Extracting sleeping index

- Because the start time may be also different between sleeping data and G-sensor data, the difference between two files should be less than 3 seconds.

22. To determine the difference of start time between sleeping data and G-sensor data

```
179       # To check whether the time of sleeping is correct
180       Datatime_gsensor<-data.frame(Datatime = Datatime_gsensor)
181       Datatime_gsensor$Datatime<-as.POSIXct(Datatime_gsensor$Datatime, origin="1970-01-01",tz="Asia/Taipei")
182       if(second(Datatime_gsensor$Datatime[1])==0&second(Datatime_sleep$Datatime[1])>55){
183         gap_of_time_sleep<-60-second(Datatime_sleep$Datatime[1])
184       }else if(second(Datatime_gsensor$Datatime[1])==1&second(Datatime_sleep$Datatime[1])>55){
185         gap_of_time_sleep<-61-second(Datatime_sleep$Datatime[1])
186       }else if(second(Datatime_gsensor$Datatime[1])==2&second(Datatime_sleep$Datatime[1])>55){
187         gap_of_time_sleep<-62-second(Datatime_sleep$Datatime[1])
188       }else if(second(Datatime_gsensor$Datatime[1])>55&second(Datatime_sleep$Datatime[1])==0){
189         gap_of_time_sleep<-second(Datatime_gsensor$Datatime[1])-60
190       }else if(second(Datatime_gsensor$Datatime[1])>55&second(Datatime_sleep$Datatime[1])==1){
191         gap_of_time_sleep<-second(Datatime_gsensor$Datatime[1])-61
192       }else if(second(Datatime_gsensor$Datatime[1])>55&second(Datatime_sleep$Datatime[1])==2){
193         gap_of_time_sleep<-second(Datatime_gsensor$Datatime[1])-62
194       }else{
195       gap_of_time_sleep<-second(Datatime_gsensor$Datatime[1])-second(Datatime_sleep$Datatime[1])
196       }
```

You can modify by yourself

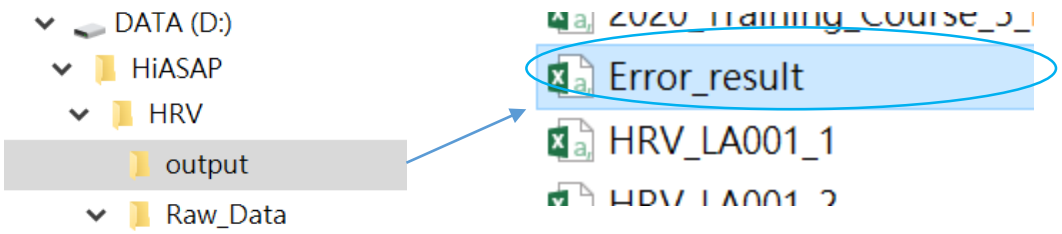
Extracting sleeping index

```
198 if(abs(gap_of_time_sleep)<=3){
199 Datatime_sleep<-Datatime_sleep %>%
200   mutate(Datatime = Datatime +gap_of_time_sleep) %>%
201   full_join(Datatime_gsensor,by = "Datatime")
202 Datatime_sleep<-Datatime_sleep %>%
203   group_by(Datatime = cut(Datatime, breaks="300 secs")) %>%
204   summarize(sleep_idx5 = max(sleep_idx,na.rm=F)
205   ) %>%
206   mutate(Datatime = ymd_hms(Datatime,tz="Asia/Taipei"))
207 }else{
208   start_time_error_sleep<-"Please check the start time of Sleep and start time of activity in result.json."
209   write.csv(start_time_error_sleep,paste0("Start_time_error_in ",subject[i],"_sleep.csv"),row.names = F)
210 }
211 }
```

If the difference is less than 3 seconds, the time will be corrected

23. To determine the sleeping index in the 5-min interval

If the difference is more than 3 seconds, the process will be terminated



Data combination for each subject

24. To merge all HRV data

```
213  # To combine all Rooti data for each subject
214  Rooti_SDNN5<-Rooti_SDNN5 %>%
215    select(test, Datatime, SDNN5)
216  Rooti_total<-data.frame(Rooti_SDNN5,Rooti_RMSSD5$RMSSD5,Rooti_lfhf5$LFHF5,Rooti_lf5$LF5,Rooti_hf5$HF5,Rooti_vlf5$VLF5,Rooti_tp5$TP5)
217  colnames(Rooti_total)[names(Rooti_total) == "Rooti_RMSSD5.RMSSD5"]<-"RMSSD5"
218  colnames(Rooti_total)[names(Rooti_total) == "Rooti_lfhf5.LFHF5"]<-"LFHF5"
219  colnames(Rooti_total)[names(Rooti_total) == "Rooti_lf5.LF5"]<-"LF5"
220  colnames(Rooti_total)[names(Rooti_total) == "Rooti_hf5.HF5"]<-"HF5"
221  colnames(Rooti_total)[names(Rooti_total) == "Rooti_vlf5.VLF5"]<-"VLF5"
222  colnames(Rooti_total)[names(Rooti_total) == "Rooti_tp5.TP5"]<-"TP5"
223  Rooti_total<-Rooti_total %>%
224    full_join(Rooti_gsensor,by = "Datatime")
225  Rooti_total<-Rooti_total %>%
226    full_join(Rooti_gsensor_raw_data,by = "Datatime")
227  if(!is.null(Rooti_online_result[[i]]$sleep$sleepStartTime)){
228  Rooti_total<-Rooti_total %>%
229    full_join(Datatime_sleep,by = "Datatime")
230  }else{
231    Rooti_total$sleep_idx5<-NA
232  }
233  Rooti_total<-Rooti_total %>%
234    full_join(Rooti_HR,by = "Datatime")
```

25. To combine activity data with HRV data

26. To combine sleeping index with HRV data

No sleeping data
-> Awake

27. To combine activity data with HRV data

Data combination for each subject

28. To re-code the “NA” as “4” for sleeping index

```
236 Rooti_total$sleep_idx5[is.na(Rooti_total$sleep_idx5)] <- 4
```

Sleeping index	Sleeping status
1	Deep sleep
2	Light sleep
3	Rapid Eye Movement (REM)
4	Awake

29. To exclude the time without HRV data

```
238 Rooti_total<-Rooti_total %>%
239   filter(!(is.na(test)))
240
241 S_no<-substr(subject[i],1,5)
242 Rooti_total<-data.frame(S_no,Rooti_total)
```

30. To add the variable of subjects’ ID to the HRV data

```
244 Rooti_total<-Rooti_total %>%
245   select(S_no,Datatime,HRsum5,HRmean5,SDNN5,RMSSD5,LFHF5,LF5,HF5,VLF5,TP5,Gsensor5,meanX5,meanY5,meanZ5,maxX5,maxY5,maxZ5,sleep_idx5)
```

31. To select variables which will use in the following analysis

Excluding the ineffective time (bad time)

32. To read the bad time of HRV monitoring

```
247       # To exclude data of ineffective time (bad time) and extreme data
248       badtime_path <- list.files(paste0(way, subject[i], "/OUTPUT/bad_time.txt"))
249
250       bad_time<-list()
251       if(length(badtime_path)==0){
252           bad_time[[i]]<-Rooti_online_result[[i]]$Q_factor$bad_min
253       }else{
254           bad_time <- read.table(paste0(way, subject[i], "/OUTPUT/bad_time.txt"))
255           for (j in 1:nrow(bad_time[[i]])) {
256               bad_time[[i]][j]<-start_time[[i]][1]+minutes(bad_time[[i]][j])
257           }
258       }
```

To automatically select the bad time from "bad_time.txt" file or "result.json" file

Name	Type
Rooti_online_result	list [7]
mode	integer [1]
Q_factor	list [1 x 4] (S3: data.frame)
total_length	integer [1]
bad_min	list [1]
good_percentage	double [1]
bad_length	integer [1]

Excluding the ineffective time (bad time)

```
260 bad_time[[i]]<-data.frame(V1 = bad_time[[i]][[1]])
261 bad_time[[i]]$V1<-as.POSIXct(bad_time[[i]]$V1, origin="1970-01-01",tz="Asia/Taipei")
```

33. To combine bad time to HRV data

```
263 Rooti_total$bad_time<-0
264 for (q in 1:(nrow(bad_time[[i]]))) {
265 for (k in 1:(nrow(Rooti_total)-1)) {
266   if(!(Rooti_total$Datatime[k]<=bad_time[[i]]$V1[q])&!(bad_time[[i]]$V1[q]<Rooti_total$Datatime[k+1])&(Rooti_total$bad_time[k]==0)){
267     Rooti_total$bad_time[k]<-0
268   }else if(!(Rooti_total$Datatime[k]<=bad_time[[i]]$V1[q])&!(bad_time[[i]]$V1[q]<Rooti_total$Datatime[k+1])&(Rooti_total$bad_time[k]==1)){
269     Rooti_total$bad_time[k]<-1
270   }else if((Rooti_total$Datatime[k]<=bad_time[[i]]$V1[q])&(bad_time[[i]]$V1[q]<Rooti_total$Datatime[k+1])&(Rooti_total$bad_time[k]==1)){
271     Rooti_total$bad_time[k]<-1
272   }else if((Rooti_total$Datatime[k]<=bad_time[[i]]$V1[q])&(bad_time[[i]]$V1[q]<Rooti_total$Datatime[k+1])&(Rooti_total$bad_time[k]==0)){
273     Rooti_total$bad_time[k]<-1
```

34. To determine whether the data time is bad time in minute

Excluding the ineffective time (bad time) and

35. To determine whether the data time is bad time in 5-min interval

```
for (q in 1:nrow(bad_time[[i]])) {
  for (k in nrow(Rooti_total)) {
    if(!(Rooti_total$Datatime[k]<=bad_time[[i]]$V1[q])&!(bad_time[[i]]$V1[q]<=(Rooti_total$Datatime[k]+minutes(4)))&(Rooti_total$bad_time[k
      Rooti_total$bad_time[k]<-0
    }else if(!(Rooti_total$Datatime[k]<=bad_time[[i]]$V1[q])&!(bad_time[[i]]$V1[q]<=(Rooti_total$Datatime[k]+minutes(4)))&(Rooti_total$bad_
      Rooti_total$bad_time[k]<-1
    }else if((Rooti_total$Datatime[k]<=bad_time[[i]]$V1[q])&(bad_time[[i]]$V1[q]<=(Rooti_total$Datatime[k]+minutes(4)))&(Rooti_total$bad_ti
      Rooti_total$bad_time[k]<-1
    }else if((Rooti_total$Datatime[k]<=bad_time[[i]]$V1[q])&(bad_time[[i]]$V1[q]<=(Rooti_total$Datatime[k]+minutes(4)))&(Rooti_total$bad_ti
      Rooti_total$bad_time[k]<-1
    }
```

36. To exclude the 5-min intervals contained bad time and the data with abnormal signals

```
    Rooti_total<-Rooti_total %>%
      filter(!(bad_time==1)) %>%
      filter(SDNN5>0 & SDNN5<400 & LFHF5>0.01 & HRmean5>40 & HRmean5<200) %>%
      select(-c(bad_time))

  write.csv(Rooti_total, paste0("HRV_",subject[i],".csv"),row.names = F)
```

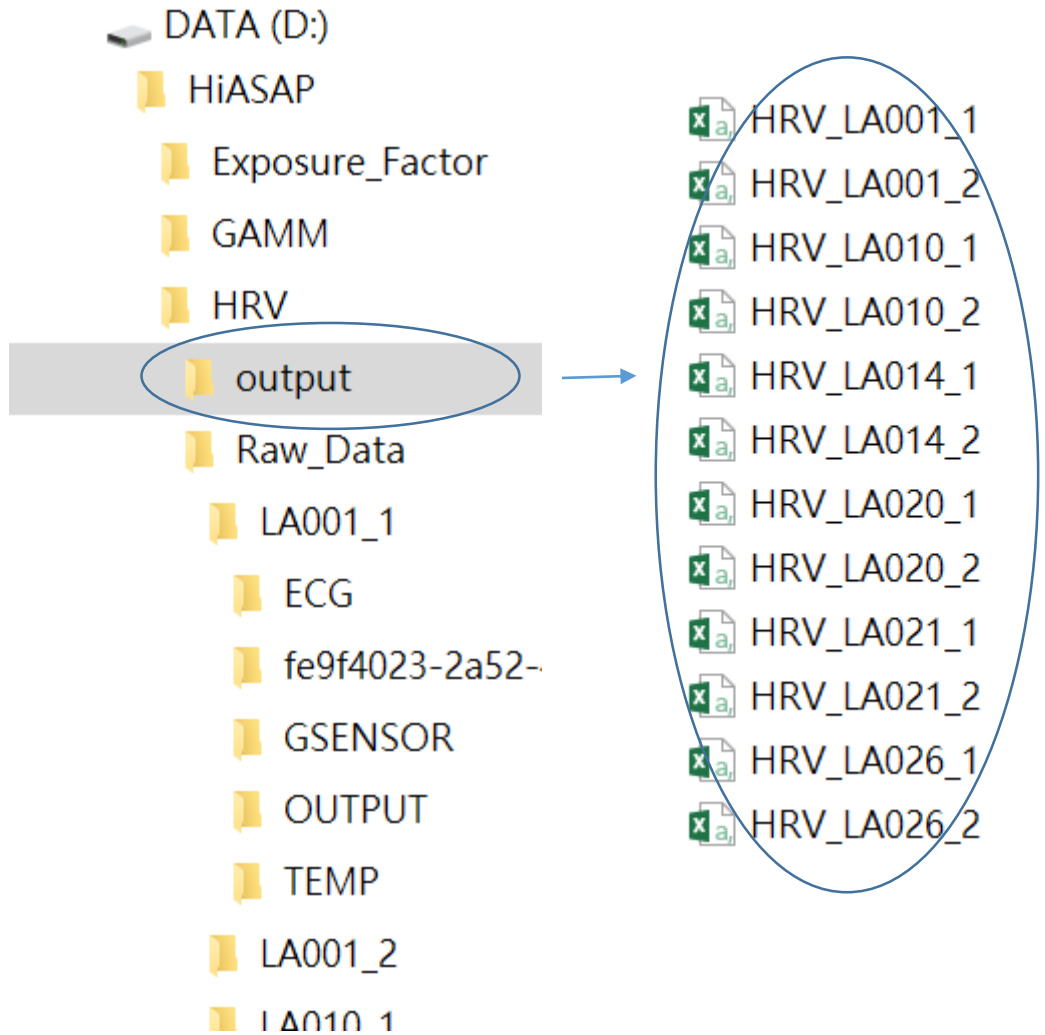
To exclude bad time

To exclude abnormal signals

Data combination for all subjects

37. To combine HRV data for all subjects

```
299 # To combine HRV data for all subjects
300 way2 <- paste0(location,"HiASAP/HRV/output")
301 aa1 <- list.files(way2,pattern="HRV")
302
303 HRV <- data.frame()
304 filename <- paste0(way2,"/",aa1[1])
305 cc <- read.csv(filename)
306 HRV <- cc
307 for(k in 2:length(aa1)){
308     filename <- paste0(way2,"/",aa1[k])
309     cc <- read.csv(filename)
310     HRV <- rbind(HRV,cc)
311 }
```



38. To create the time-related variables for data combination

```
313 # To create the time variables (year, month, day, hour and minute) for the following data matching
314 library(lubridate)
315 yy<-c()
316 mm<-c()
317 dd<-c()
318 hh<-c()
319 mn<-c()
320 for(l in 1:dim(HRV)[1]){
321     if(nchar(as.character(HRV$Datatime[l]))==14){
322         yy[l] <- as.numeric(substr(HRV$Datatime[l],1,4))
323         mm[l] <- as.numeric(substr(HRV$Datatime[l],6,6))
324         dd[l] <- as.numeric(substr(HRV$Datatime[l],8,8))
325         hh[l] <- as.numeric(substr(HRV$Datatime[l],10,11))
326         mn[l] <- as.numeric(substr(HRV$Datatime[l],13,14))
327     }else{
328         if(nchar(as.character(HRV$Datatime[l]))==15){
329             yy[l] <- as.numeric(substr(HRV$Datatime[l],1,4))
330             mm[l] <- as.numeric(substr(HRV$Datatime[l],6,6))
331             dd[l] <- as.numeric(substr(HRV$Datatime[l],8,9))
332             hh[l] <- as.numeric(substr(HRV$Datatime[l],11,12))
333             mn[l] <- as.numeric(substr(HRV$Datatime[l],14,15))
334     }else{
335             yy[l] <- as.numeric(substr(HRV$Datatime[l],1,4))
336             mm[l] <- as.numeric(substr(HRV$Datatime[l],6,7))
337             dd[l] <- as.numeric(substr(HRV$Datatime[l],9,10))
338             hh[l] <- as.numeric(substr(HRV$Datatime[l],12,13))
339             mn[l] <- as.numeric(substr(HRV$Datatime[l],15,16))
340         }
```

To avoid the formats of date may be different

Ex: 2020-03-03 / 2020-3-10 / 2020-3-1 ….

- Year
- Month
- Day
- Hour
- Minute

39. To create a variable of 30-minute interval of each hour for merging data with TAD

```
343 mn_30 <- c()
344 for (l in 1:length(mn)) {
345     if(mn[l] < 30){
346         mn_30[l] <- 1
347     }else{
348         mn_30[l] <- 2
349     }
350 }
```

Year	Month	Day	Hour	Minute	Minute_30
2018	10	8	13	46	2
2018	10	8	13	51	2
2018	10	8	13	56	2
2018	10	8	14	1	1
2018	10	8	14	6	1
2018	10	8	14	11	1

Time between 30 to 59 minutes -> 2

Time between 0 to 29 minutes -> 1

```
351 date_1 <- c(ymd_hm(paste0(yy,"-",mm,"-",dd," ",hh,":",mn)))
```

40. To format the date variable

Ex: 2020-01-01 14:11

```
HRVfinal <- data.frame()
for(j in 1:dim(HRV)[1]){
    HRVfinal[j,1]<-date_1[j]
    HRVfinal[j,2]<-yy[j]
    HRVfinal[j,3]<-mm[j]
    HRVfinal[j,4]<-dd[j]
    HRVfinal[j,5]<-hh[j]
    HRVfinal[j,6]<-mn[j]
    HRVfinal[j,7]<-mn_30[j]
    HRVfinal[j,8]<-HRV[j,1]
    HRVfinal[j,9]<-HRV[j,3]
    HRVfinal[j,10]<-HRV[j,4]
    HRVfinal[j,11]<-HRV[j,5]
    HRVfinal[j,12]<-HRV[j,6]
    HRVfinal[j,13]<-HRV[j,7]
    HRVfinal[j,14]<-HRV[j,8]
    HRVfinal[j,15]<-HRV[j,9]
    HRVfinal[j,16]<-HRV[j,10]
    HRVfinal[j,17]<-HRV[j,11]
    HRVfinal[j,18]<-HRV[j,12]
    HRVfinal[j,19]<-HRV[j,13]
    HRVfinal[j,20]<-HRV[j,14]
    HRVfinal[j,21]<-HRV[j,15]
    HRVfinal[j,22]<-HRV[j,16]
    HRVfinal[j,23]<-HRV[j,17]
    HRVfinal[j,24]<-HRV[j,18]
    HRVfinal[j,25]<-HRV[j,19]
}
```

41. To combine time-related variables with HRV data

Data export

42. To export the final dataset of HRV data for all subject

```
colnames(HRVfinal)<-c("Date","Year","Month","Day","Hour","Minute","Minute_30","S_no","HRsum5","HRmean5","RMSSD5","SDNN5","LFHF5","LF5","HF5","VLF5
outputname<-"HRV_5 minute_All.csv"
write.csv(HRVfinal,outputname,row.names=FALSE,na="")
```

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	Date	Year	Month	Day	Hour	Minute	Minute_3(	S_no	HRsum5	HRmean5	RMSSD5	SDNN5	LFHF5	LF5	HF5	VLF5	TP5	Gsensor5	Mear
2	2019/3/8 20:44	2019	3	8	20	44	2	LA001	395	79	55	32	2.11388	2724.052	1288.647	1042.454	5280.367	225213	-91.
3	2019/3/8 20:49	2019	3	8	20	49	2	LA001	381	76	21	11	5.30485	148.0447	27.90743	369.4822	559.5795	236084	-83.
4	2019/3/8 20:54	2019	3	8	20	54	2	LA001	378	75	22	13	2.02665	165.0012	81.41592	308.2564	572.0915	237179	-112
5	2019/3/8 20:59	2019	3	8	20	59	2	LA001	385	77	25	11	7.63461	249.6129	32.69492	493.2865	785.7868	253149	-99.
6	2019/3/8 21:04	2019	3	8	21	4	1	LA001	401	80	50	10	8.13229	324.7405	39.93225	2188.406	2562.708	275926	-58.
7	2019/3/8 21:09	2019	3	8	21	9	1	LA001	393	78	46	12	5.59928	343.4503	61.33825	1564.531	1983.003	342981	-76.
8	2019/3/8 21:19	2019	3	8	21	19	1	LA001	405	81	24	13	3.47165	226.2616	65.17399	432.4855	740.236	242236	-104
9	2019/3/8 21:24	2019	3	8	21	24	1	LA001	375	75	21	11	2.13299	98.88472	46.35963	307.0851	460.9489	176192	-4.
10	2019/3/8 21:29	2019	3	8	21	29	1	LA001	373	74	22	11	2.37502	104.9368	44.18362	366.4598	521.509	136830	-74.
11	2019/3/8 21:34	2019	3	8	21	34	2	LA001	375	75	25	10	2.12332	96.44783	45.42303	615.4884	761.8169	133101	-74.
12	2019/3/8 21:39	2019	3	8	21	39	2	LA001	377	75	23	10	3.02831	142.2082	46.98023	264.4435	459.7175	136872	5(

Thank you for your attention