Chapter 2. Data visualization

[presentation] (./pdf/ppt2.pdf) **[book] (./pdf/book2.pdf)**

CHAPTER OBJECTIVES

In this chapter, we introduce the following.

- Visualization of qualitative data in Section 2.1.
  If data is categorical, bar graph, pie chart, band graph, and line graph are used to visualize data. 『eStat』 can visualize the raw data of a categorical variable. If a frequency table summarizes the raw data of a categorical variable, 『eStat』 can plot similar graphs using the frequency table. Categorical data by a group variable is also discussed. If there are two or more qualitative variables, a bar graph matrix is used to visualize data. We can visualize text data using a word cloud.
- Visualization of quantitative data in Section 2.2.
  If there is a single quantitative variable, dot graph, histogram, stem and leaf plot are used to visualize data. If there are two or more quantitative variables, scatterplot and scatterplot matrix are used to visualize data. If a quantitative variable is observed over time, line graph or time series plot can be used to visualize data.

2.1 Visualization of qualitative data

Data on gender for students in a classroom who are either male or female are referred to as qualitative and categorical data. Data on marital status for company employees who are either single or married are also qualitative and categorical. Bar graph, pie chart, band graph, and line graph are used to visualize the categorical data for an exploratory data analysis.

A bar graph is a graph that presents qualitative data with rectangular bars. Each bar height is proportional to the frequency of the bar category. Therefore, the frequencies of all categories in a categorical variable can be easily compared by watching the bars' heights. We usually put some space between the rectangular bars to emphasize that they represent the distinct categories of a variable. The bar chart's rectangular bars can be plotted vertically or horizontally. One axis of the chart shows all categories of a variable, and the other axis represents the frequencies of each category. If the frequency of each category is represented as the vertical height of a bar drawn up and down in the bar graph, it is called a vertical bar graph. A bar can also be drawn left and right, and its length is proportional to the frequency of each category. It is called a horizontal bar graph.

A pie chart is a graph that shows frequencies of all categories of the analysis variable by dividing a pie (circle) into pieces with different colors depending on the angle, which is proportional to the frequency of each category. We usually draw the largest piece in a clockwise order starting from 12 o'clock so that the ratio can be compared well. A doughnut chart that removes a center circle from the pie chart can also be used.

A band graph is similar to the ratio bar graph that shows frequencies of all categories of the analysis variable by dividing a rectangle into square pieces with different colors, which are proportional to frequencies of all categories. It is also similar to the pie chart. The square pieces can be sorted in descending order by the frequencies of each category, but 『eStat』 draws the square pieces in the order of category values of a categorical variable.

A line graph shows frequencies (or values) of all categories of an analysis variable in a two-dimensional graph. The X-axis shows the names of categories, and the Y-axis represents the scale of frequencies (or values) of all categories. Each pair of the values, the category name and its frequency, is marked as a point in a two-dimensional coordinate plane, and two adjacent points are connected with a line. The line graph may be similar to the vertical bar graph, which connects only the top centers of each bar. The line graph is usually used to visualize time-dependent data to watch its trend over time. For example, the yearly amount of exports in a country can be visualized using the line graph.

Gender is a typical categorical variable with two categories, 'male' and 'female.' Suppose you investigated 10 students based on their gender in a class and reported the result as follows.

male, female, male, female, male. male, male, female, male, female

This data is called the **raw data** of the gender variable. For statistical packages, the raw data are usually arranged in columns, as shown in Table 2.1.1.

Table 2.1.1 Raw data of the gender in a class
Gender
male
female
male
female
male
male
male
female
male
female

Numeric coded values such as 1 for male and 2 for female can be used for convenience because some packages do not allow characters on data values. 『eStat』 system allows the raw data of both with and without coding.

If you counted the number of ‘male’ and ‘female’ students in the above raw data, 6 males and 4 females, the result of frequencies is usually reported, as shown in Table 2.1.2.

Table 2.1.2 Frequency data of the gender in a class

Gender	Students
Male	6
Female	4

This data is called the **frequency data** of the gender variable. If the raw data of a categorical variable are summarized by frequency data, 『eStat』 can plot the graphs using both raw and frequency data.

If the number of data increases, counting the number of cases in each category from the raw data of a categorical variable to make the frequency data is not easy. One of the essential functions of a statistical package is to organize the raw data into frequency data by counting the number of cases in each category. Since generating the frequency data from the massive raw data is so difficult for non-expert people, most governmental institutions usually provide the census statistics to the public in the form of frequency data such as population by gender or population by region. We can download these frequency data from the governmental web pages as an Excel file. An Excel file can be saved as a text file in CSV (comma-separated value) format which can be loaded by 『eStat』 for data processing and analysis (refer Appendix A).

This section discusses the visualization of the raw data of a categorical variable without a group and with a group variable. Section 2.1.2 discusses the visualization of frequency data without a group and with a group variable, which can be found in textbooks of elementary, middle school, high school, and in governmental publications. Section 2.1.3 discusses the visualization of several categorical variables. Text data is a special case of qualitative data. Section 2.1.4 discusses the visualization of text data using word cloud.

2.1.1 Visualization of raw data of a categorical variable

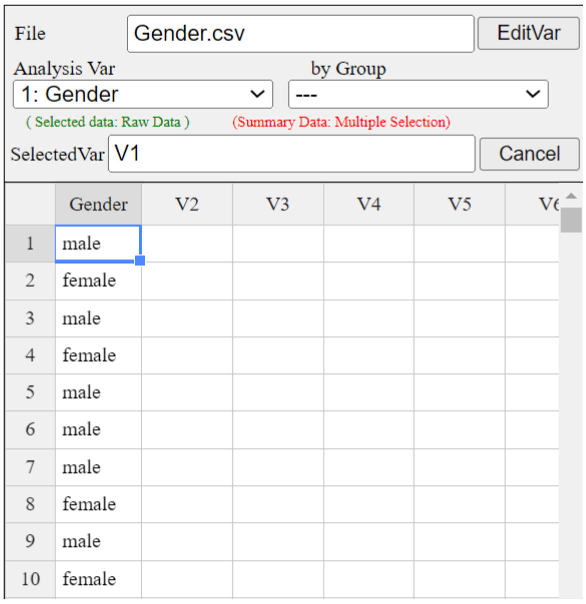
Visualization of raw data of a single variable

Consider the following example to visualize the raw data of the gender variable in Table 2.1.1 using 『eStat』.

Example 2.1.1 (Visualization of raw data on gender variable)
Enter the raw data of Table 2.1.1 to the sheet of 『eStat』 and save it as a file in CSV format. Then, visualize the data with a bar graph, pie chart, band graph, and line graph using 『eStat』. Analyze the graphs and prepare a report using MS Word (or any word processor you prefer).

Answer

Enter the data of Table 2.1.1 to the sheet of 『eStat』 as in <Figure 2.1.1> and enter a variable name of V1 as ‘Gender’ using [Edit Var] button above the sheet. Save this file as Gender.csv by clicking [csv Save] button above the sheet.

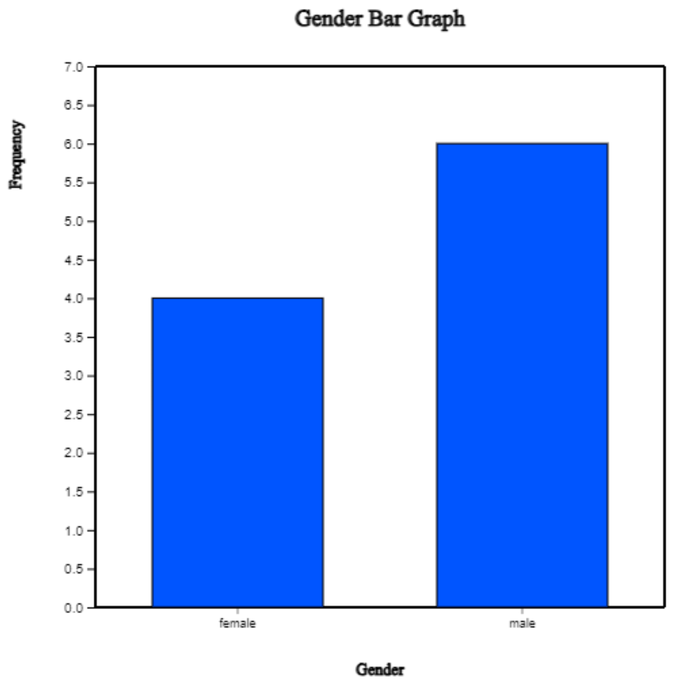


<Figure 2.1.1> Data input in 『eStat』

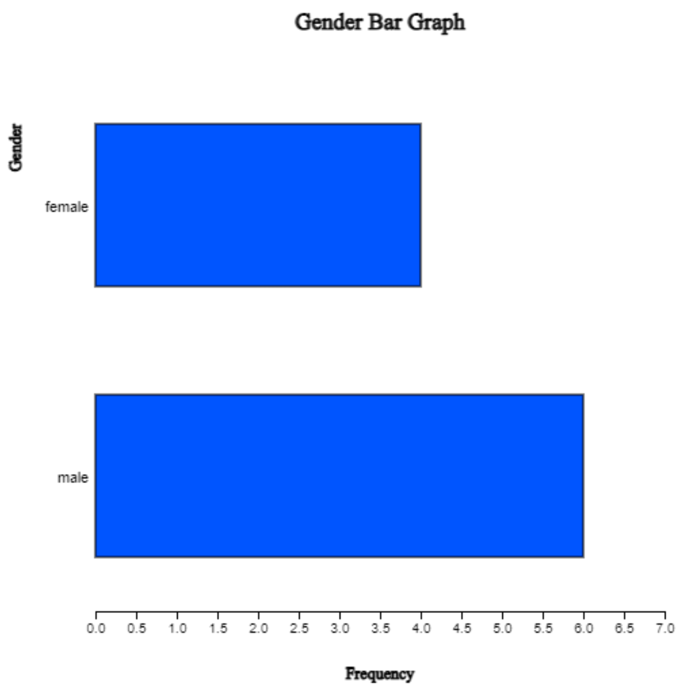
Click the Gender variable name, then the selected variable (V1 is the name of the 1st variable) will appear in the 'Selected Var' box above the sheet. You can also select the variable ‘1: Gender’ using the 'Analysis Var' combo box. above the sheet as shown in <Figure 2.1.1>.

When a variable is selected, a vertical bar graph, the default graph of 『eStat』, is drawn as in <Figure 2.1.2>. The height of each bar (rectangle) is proportional to the frequency of each category in the gender variable. Therefore the frequencies of both the male and the female categories can be easily compared by looking the heights of the bars. The bar graph shows that the number of male students is larger than that of female students.

A vertical bar graph that draws bars up and down, as in <Figure 2.1.2> is widely used, but a horizontal bar graph that draws bars from left to right is often used if there are many categories. By clicking on the horizontal bar graph icon above the Graph window, a horizontal bar graph, as in <Figure 2.1.3> will appear in the Graph window. The frequency of each bar is displayed by checking the ‘Frequency’ box below the graph.

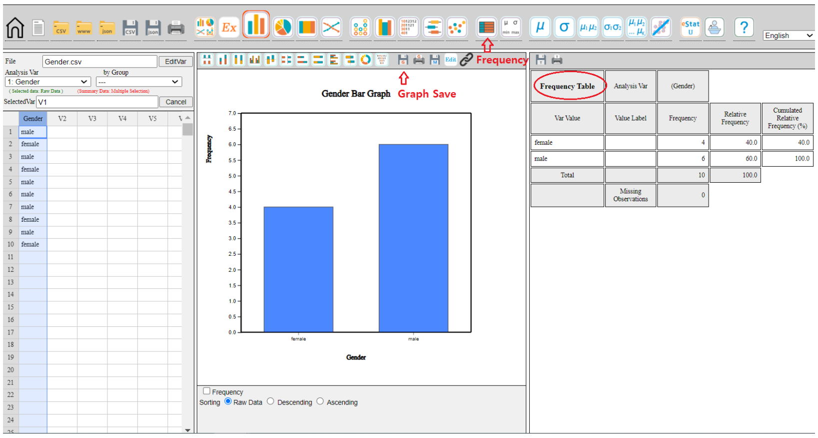


<Figure 2.1.2> Vertical bar graph of the number of male and female students.



<Figure 2.1.3> Horizontal bar graph of the number of male and female students.

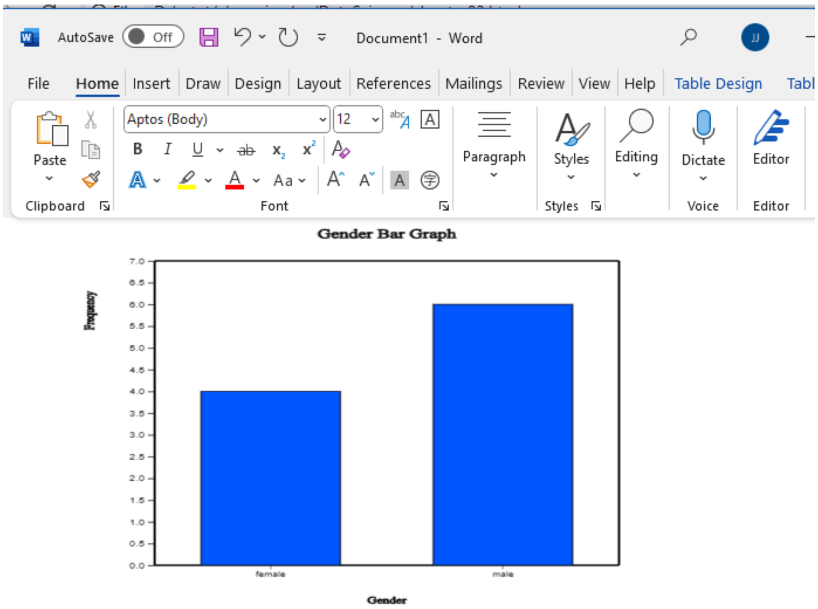
By clicking the ‘Graph Save’ icon above the Graph window, the current graph of the Graph window will be saved with a file name ‘eStatGraph.png’ after showing on the main screen for a short time. If you click the 'Frequency Table' button on the main menu icon, the frequency table corresponding to the bar graph appears on the right-hand side of the main screen.



<Figure 2.1.4> Graph is saved by clicking the ‘Graph Save’ icon

The location of the saved graph file is the download folder specified in your computer system. If you save another graph, eStatGraph(1).png will be created in the download folder. The number in parentheses of the file name will be increased whenever you save a new graph.

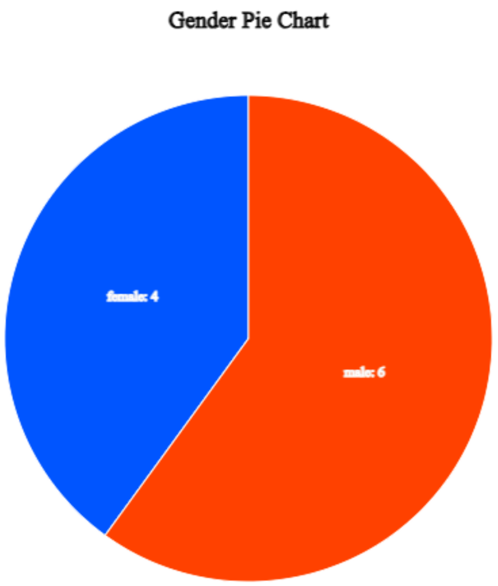
You can copy this graph file from the download folder and paste it into MS Word as in <Figure 2.1.5>. You can copy the frequency table of the main screen and paste it into Word. You can also write comments about the graph if necessary.



Frequency Table	Analysis Var	(Gender)		
Var Value	Value Label	Frequency	Relative Frequency	Cumulated Relative Frequency (%)
female		4	40.0	40.0
male		6	60.0	100.0
Total		10	100.0	
	Missing Observations	0		

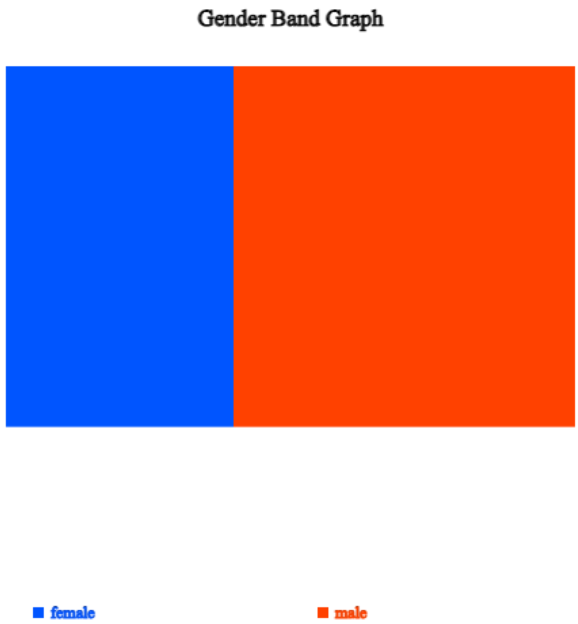
<Figure 2.1.5> Copied graph file of 『eStat』 to MS Word

Click on the pie chart icon to display a pie chart as in <Figure 2.1.6> and click on the doughnut graph icon to display a doughnut graph, which is a pie chart, but a small middle circle is cut off. The pie chart shows frequencies of the number of male and female students by dividing a pie (circle) into pieces with two colors depending on angles that are proportional to each category's frequencies.



<Figure 2.1.6> Pie chart of the number of male and female students.

Click on the band graph icon to display a band graph as in <Figure 2.1.7>. A band graph is a variant of the pie chart that divides a rectangle into square pieces proportional to each category's frequencies. It is named after a rectangular shape with multiple square pieces which look like a band.



<Figure 2.1.7> Band graph of the number of male and female students.

We can draw a bar graph after counting the frequencies of all variable categories. If there is another categorical variable, called a group variable, we can count the frequencies of all categories of the first categorical variable for each category of the second (group) categorical variable. the first categorical variable can be counted for each category of the second (group) categorical variable. For example, we can count the number of single and married employees in the male and female categories. We can draw two bar graphs of the marital status for both the male and the female categories so that both graphs have the same scale of the Y-axis to compare easily the frequencies of the male category with the frequencies of the female category. This graph is called a separate bar graph of the marital status by gender variable. In this case, the gender variable is called a group variable, and the marital status is called an analysis variable.

If a variable is analyzed by using a group variable, there are many variants of bar graphs which visually compares all categories of the group variable. A stacked bar graph divides a single bar, which represents the frequency of a category of the analysis variable, into pieces with different colors, which are proportional to the frequency of each category of the group variable. A ratio bar graph draws that all bars (rectangles) of each category of the analysis variable have the same height and divides each bar into pieces with different colors, which are proportional to the frequencies of each category of the group variable. A side-by-side bar graph is that in each category of the analysis variable rectangular bars of all categories of the group variable are drawn side-by-side ways for comparison using the same scale. If there are only two categories of the group variable, a two-sided bar graph (or a bi-lateral bar graph) can be used, which draws bars of one category of the group variable in one side and bars of the other category of the group variable in the opposite direction. The direction can be either the left and right side of the Y-axis or the above and below of the X-axis.

Visualization of raw data with a group variable

Consider an example to visualize one categorical variable by using the other group variable.

Example 2.1.2 (Customer survey data of a computer store)
Twenty customers who visited a computer store were surveyed, and the results of the survey on the gender, age, monthly income, credit status, and whether to purchase were summarized as in [Table 2.1.3].

Table 2.1.3 Survey on twenty customers of a computer store

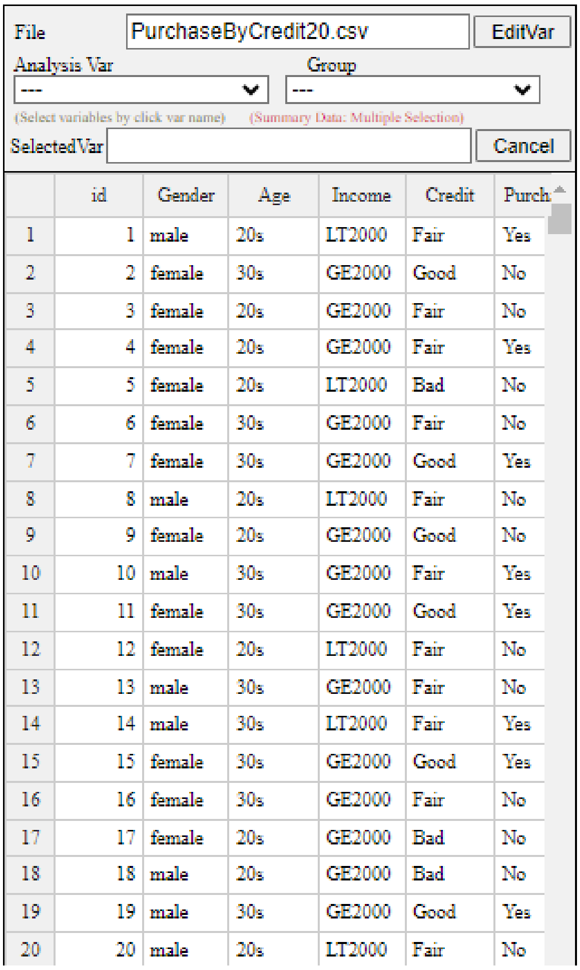
id	Gender	Age	Income	Credit	Purchase
1	male	20s	LT2000	Fair	Yes
2	female	30s	GE2000	Good	No
3	female	20s	GE2000	Fair	No
4	female	20s	GE2000	Fair	Yes
5	female	20s	LT2000	Bad	No
6	female	30s	GE2000	Fair	No
7	female	30s	GE2000	Good	Yes
8	male	20s	LT2000	Fair	No
9	female	20s	GE2000	Good	No
10	male	30s	GE2000	Fair	Yes
11	female	30s	GE2000	Good	Yes
12	female	20s	LT2000	Fair	No
13	male	30s	GE2000	Fair	No
14	male	30s	LT2000	Fair	Yes
15	female	30s	GE2000	Good	Yes
16	female	30s	GE2000	Fair	No
17	female	20s	GE2000	Bad	No
18	male	20s	GE2000	Bad	No

19	male	30s	GE2000	Good	Yes
20	male	20s	LT2000	Fair	No

Enter the data of Table 2.1.3 to the sheet of 『eStat』 and save it as a file in CSV format. Using this data, draw bar graph variants on the purchase variable (called '**analysis variable**') by the gender variable (called a '**group variable**') with 『eStat』. Find a frequency table corresponding to these graphs.

Answer

We entered the data of Table 2.1.3 to the sheet of 『eStat』 as in <Figure 2.1.8> and assigned variable names of V1, V2, V3, V4, V6 as 'id', 'Gender', 'Age', 'income', 'Credit', 'Purchase' respectively using [Edit Var] button above the sheet. The data is saved in 『eStat』 system at Ex -> /DataScience/PurchaseByCredit20.csv.

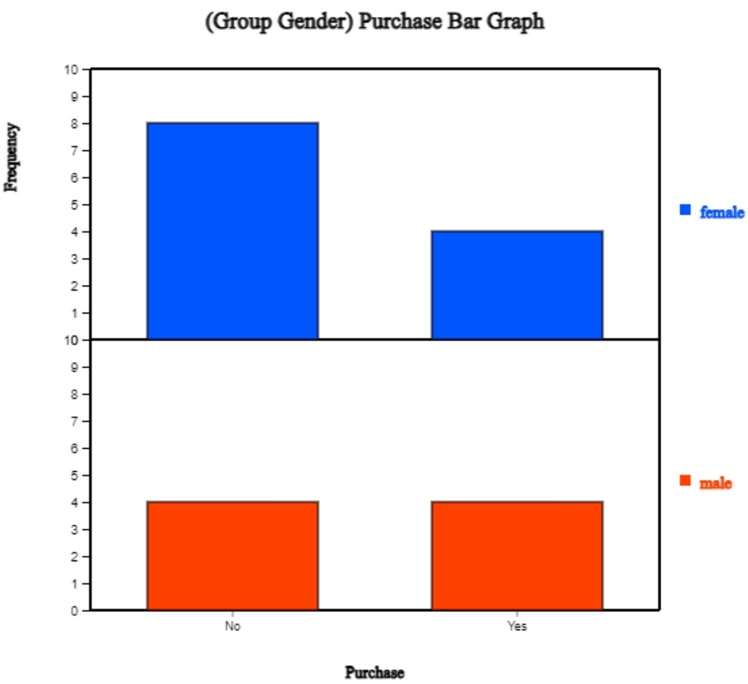


	id	Gender	Age	Income	Credit	Purch
1	1	male	20s	LT2000	Fair	Yes
2	2	female	30s	GE2000	Good	No
3	3	female	20s	GE2000	Fair	No
4	4	female	20s	GE2000	Fair	Yes
5	5	female	20s	LT2000	Bad	No
6	6	female	30s	GE2000	Fair	No
7	7	female	30s	GE2000	Good	Yes
8	8	male	20s	LT2000	Fair	No
9	9	female	20s	GE2000	Good	No
10	10	male	30s	GE2000	Fair	Yes
11	11	female	30s	GE2000	Good	Yes
12	12	female	20s	LT2000	Fair	No
13	13	male	30s	GE2000	Fair	No
14	14	male	30s	LT2000	Fair	Yes
15	15	female	30s	GE2000	Good	Yes
16	16	female	30s	GE2000	Fair	No
17	17	female	20s	GE2000	Bad	No
18	18	male	20s	GE2000	Bad	No
19	19	male	30s	GE2000	Good	Yes
20	20	male	20s	LT2000	Fair	No

<Figure 2.1.8> Data input in 『eStat』

Click the first variable name 'Purchase' and then the second variable name 'Gender'. Selected variables will appear in the 'Selected Var' box above the sheet. You can select the variable '6: Purchase' using the combo box of the 'Analysis Var' and the variable '2: Gender' using the combo box of the 'By Group' above the sheet.

When variables are selected, a vertical bar graph with a group, the default graph of 『eStat』, is drawn as in <Figure 2.1.9>. The bar graphs for males and females are drawn separately, called a 'Separate bar graph'. By clicking the 'Frequency' box below the graph, the frequency of each bar will be displayed as in <Figure 2.1.10>.

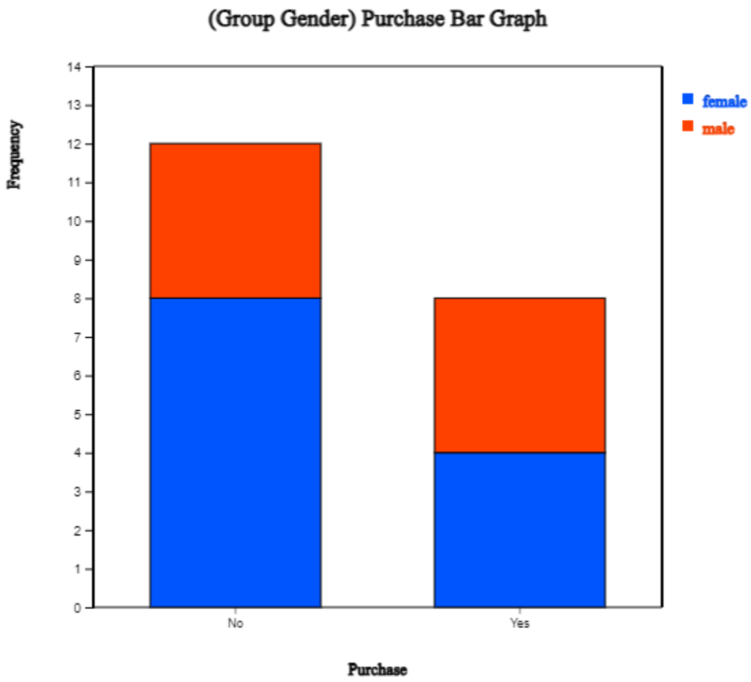


<Figure 2.1.9> Vertical separate bar graph on Purchase by male and female group.

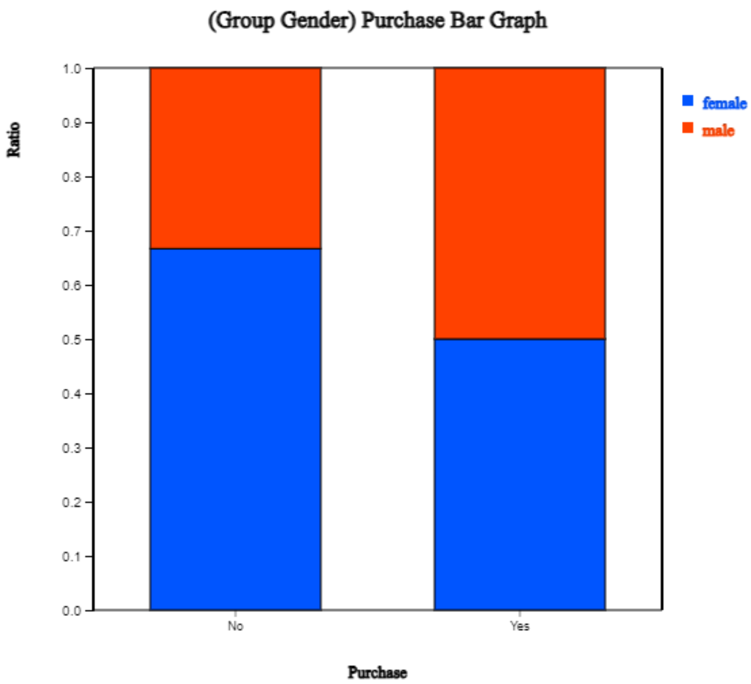
Cross Table	Col Variable	(Purchase)			
Row Variable (Gender)	No	Yes	Total		
female Row % Col % Tot %	8 66.7% 66.7% 40.0%	4 33.3% 50.0% 20.0%	12 100.0% 60.0%		
male Row % Col % Tot %	4 50.0% 33.3% 20.0%	4 50.0% 50.0% 20.0%	8 100.0% 40.0%		
Total Row % Col %	12 60.0% 100.0%	8 40.0% 100.0%	20 100.0% 100.0%		
	Missing Observations	0			
Independence Test					
Sum of χ^2 value	0.556	deg of freedom	1	p-value	0.4561

<Figure 2.1.10> Two-dimensional frequency table on Purchase by male and female group.

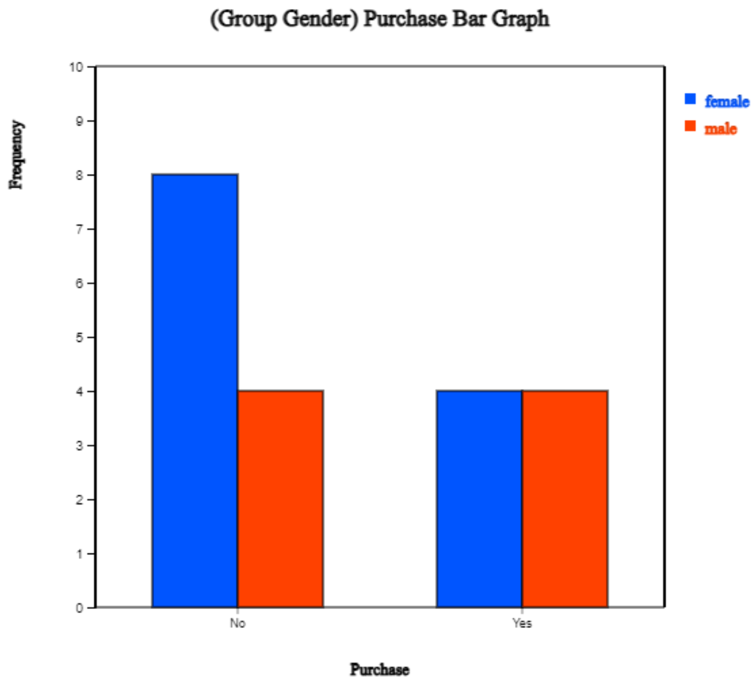
The sub-icon menu above of the graph shows several variants of bar graph when there is a group variable. They are vertical 'Separate', 'Stacked' as in <Figure 2.1.11>, 'Ratio' as in <Figure 2.1.12>, 'Side-by-side' as in <Figure 2.1.13>, 'Two-sided' as in <Figure 2.1.14> and horizontal bar graphs.



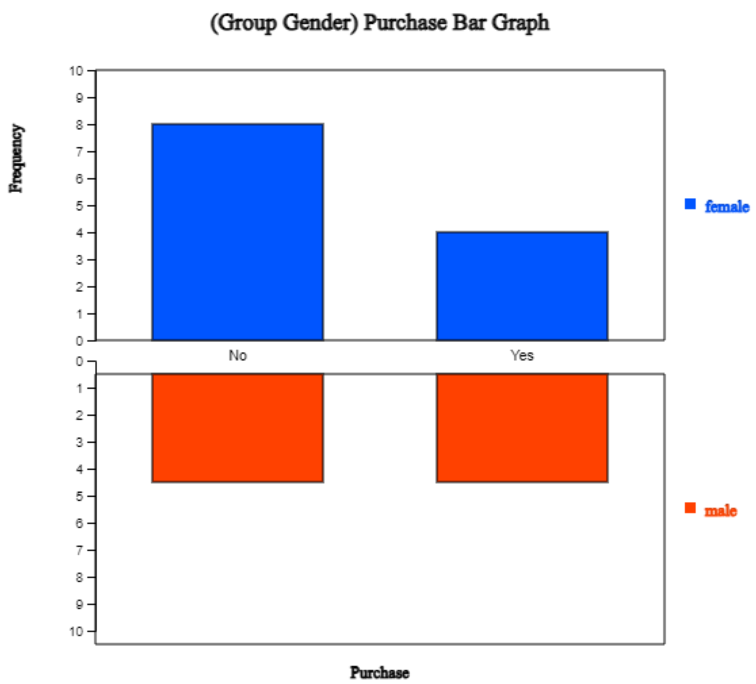
<Figure 2.1.11> Vertical stacked bar graph on Purchase by male and female group.



<Figure 2.1.12> Vertical ratio bar graph on Purchase by male and female group.



<Figure 2.1.13> Vertical side-by-side bar graph on Purchase by male and female group.



<Figure 2.1.14> Vertical bi-lateral bar graph on Purchase by male and female group.

Practice 2.1.1 (Preference of Mathematics by Gender)
In an elementary school, the gender (1: male, 2: female) and math preference (1: good, 2: ordinary, 3: no) of students were surveyed and saved at the following location of 『eStat』 system.

[Ex] ⇨ DataScience ⇨ MathPreferenceByGender.csv.

Draw a bar graph, a pie chart and a band graph of the math preference by gender.

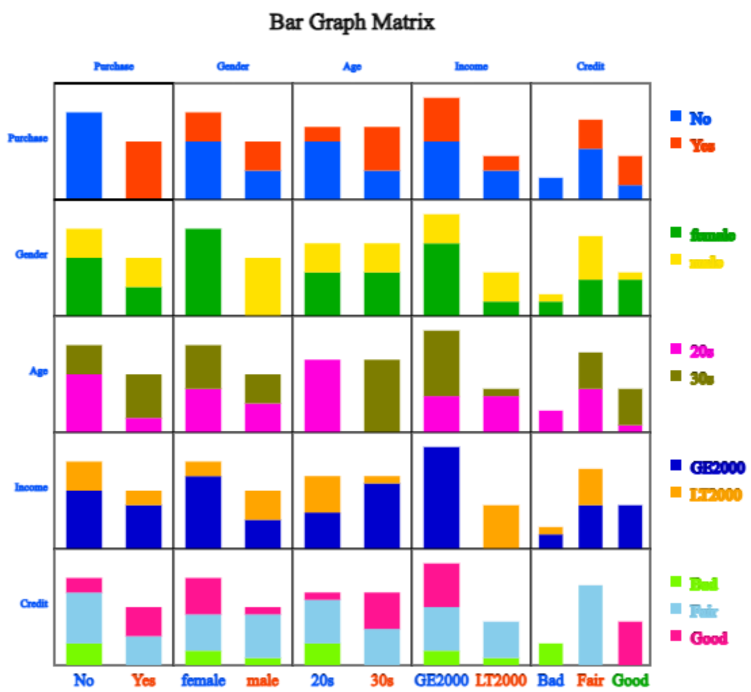
Visualization of raw data of several varaibles

If there are two or more qualitative variables, a bar graph matrix is used to visualize data. If there are m number of variables, $m \times m$ matrix of bar graphs is visualized. In each column variable, bar graph is visualized based on the frequencies of each value of the column variable by using the row variable as a group variable. The bar graph matrix is useful for deciding which variable is useful for classification analysis.

Example 2.1.3 (Bar graph matrix)
Draw a bar graph matrix using the five variables in Table 2.1.3, gender, age, income, credit and purchase.

Answer

After you load the data file of Table 2.1.3, /DataScience/PurchaseByCredit20.csv, click the bar graph matrix icon . Click 'Purchase' as 'Group' variable and select 'Gender', 'Age', 'Income', 'Credit' as 'Analysis Var'. Then, the bar graph matrix, as in <Figure 2.1.15>, will appear in the graph window.



<Figure 2.1.15> Bar graph matrix using the data in Table 2.1.3.

You can practice a 'Bar graph matrix' using the module in『eStatU』, 'Ch 2 Bar graph Matrix' as following example.

[Bar Graph Matrix]

Bar Graph Matrix - Muti-dim Frequency Table

Menu

	Variable Name	Data Input
X_1	Purchase	Yes No No Yes No No Yes No No Yes Yes No No Yes Yes No No No Yes No Yes N
X_2	Gender	male female female female female female female male female male female female
X_3	Age	20s 30s 20s 20s 20s 30s 30s 20s 20s 30s 30s 20s 30s 30s 30s 30s 20s 20s 30s 2
X_4	Income	LT2000 GE2000 GE2000 GE2000 LT2000 GE2000 GE2000 LT2000 GE2000 GE2
X_5	Credit	Fair Good Fair Fair Bad Fair Good Fair Good Fair Good Fair Fair Fair Good Fair B
X_6		

Execute Erase Data

Graph Save Cross Table Matrix Muti-dim Frequency Table Table Save

2.1.2 Visualization of frequency data of a categorical variable

Visualization of frequency data of a single categorical variable

If you counted the number of ‘male’ and ‘female’ students in the raw data, as in Table 2.1.1, the frequency result is reported in Table 2.1.4.

Table 2.1.4 Frequency data of the gender in a class

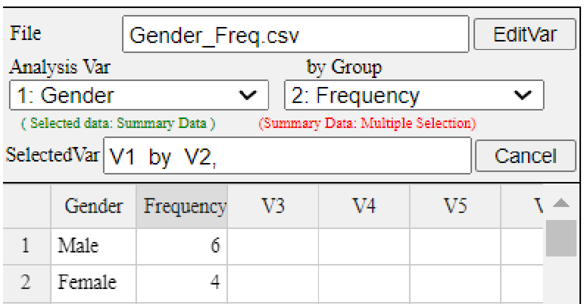
Gender	Frequency
Male	6
Female	4

『eStat』 can also plot the graphs using this frequency data of the gender variable as the following example.

Example 2.1.4 (Frequency data of gender)
Enter the frequency data of Table 2.1.4 to the sheet of 『eStat』 and save it as a file in CSV format. Using this data, draw a bar graph, a pie chart and a band graph with 『eStat』. Analyze the graphs.

Answer

Enter the data of Table 2.1.4 to the sheet of 『eStat』 as in <Figure 2.1.16> and enter a variable name of V1 as ‘Gender’ and of V2 as ‘Frequency’ using [Edit Var] button above the sheet.

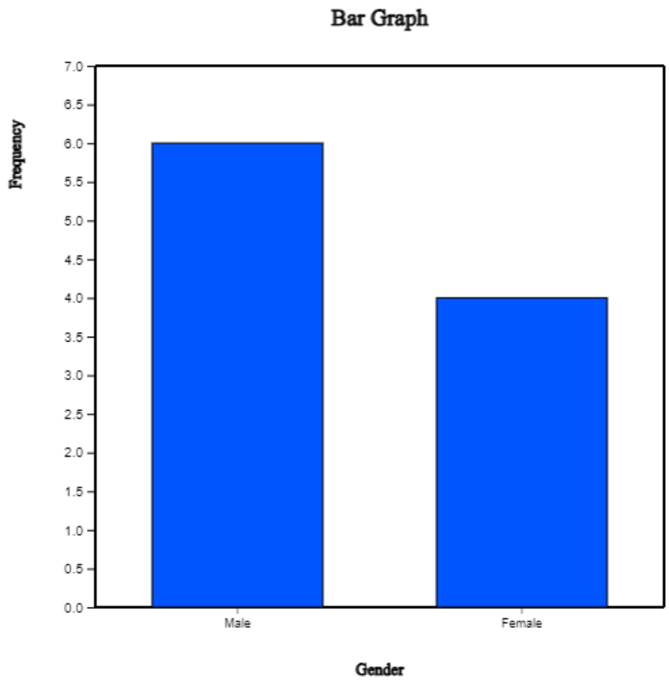


<Figure 2.1.16> Data input of frequency data in Table 2.1.4

Click the first variable name 'Gender', and then the second variable name 'Frequency'. Selected variables will appear in the 'Selected Var' box above the sheet. You can select the variable ‘1: Gender’ using the combo box of the 'Analysis

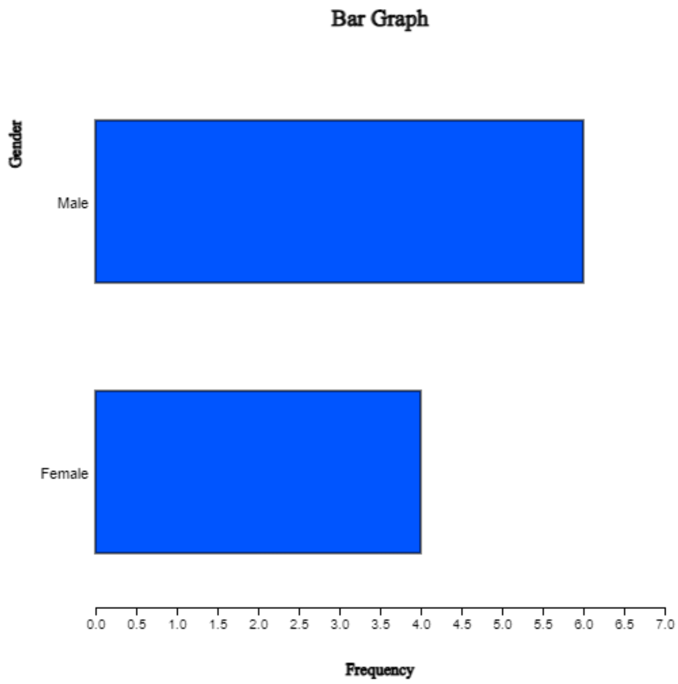
Var' and the variable ‘2: Frequency’ using the combo box of the 'By Group' above the sheet as shown in <Figure 2.1.16>.

When variables are selected, a vertical bar graph, which is the default graph of 『eStat』 is drawn as in <Figure 2.1.17>. The height of each bar (rectangle) is proportional to the frequency of each category in the gender variable. Therefore, the frequencies of both the male and the female categories can be easily compared by watching the heights of the bars. The bar graph shows that the number of male students is larger than that of female students.



<Figure 2.1.17> Vertical bar graph using the frequency data in Table 2.1.4

A vertical bar graph that draws bars up and down, as in <Figure 2.1.17> is widely used, but a horizontal bar graph, that draws bars from left to right is often used if there are many categories. By clicking on the horizontal bar graph icon above the Graph window, a horizontal bar graph, as in <Figure 2.1.18> will appear in the Graph window. By checking the 'Frequency’ box below the graph, the frequency of each bar, will be displayed.



<Figure 2.1.18> Horizontal bar graph using the frequency data in Table 2.1.4

Click on the pie chart icon to display a pie chart. Click on the band graph icon to display a band graph.

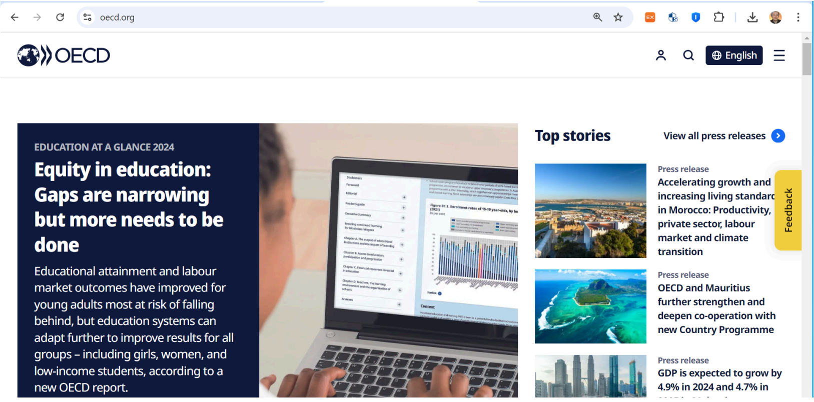
Visualization of frequency table of several groups

Many governmental institutions such as the UN, OECD, and EU release their statistics to the public as frequency data, which can be downloaded as an Excel file or a text file in CSV format. The following example shows how to download a file from the OECD and how to draw graphs using this file.

Example 2.1.5 (Life Expectancy at Birth : Source OECD)
From the home page of the OECD, https://www.oecd.org, download a data file of the life expectancy at birth. Copy the columns of the country name and 2017 data at the last column to 『eStat』 system and save it as a file in CSV format. Using this data, draw a vertical bar graph and a horizontal bar graph in descending order of the life expectancy. Analyze the graphs.

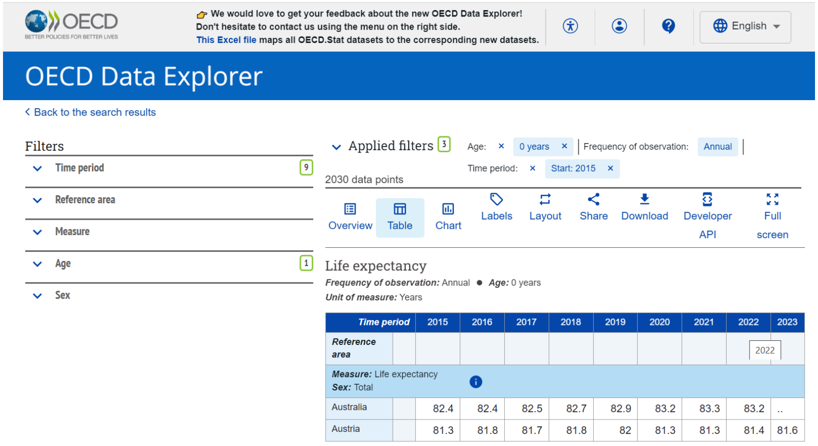
Answer

The main screen of the OECD website, https://www.oecd.org, as of September 2024 is in <Figure 2.1.19>.



<Figure 2.1.19> OECD home page

Select the menu at the top right-hand corner (three lines) and select **Data > Key Indicators**, then select **Health** in **Policy areas** of **Filters**. If you choose **Life expectancy at birth**, you can see the graph of Life expectancy at birth. You can find **Access now** button below the graph at the section on **Access the source dataset in Data Explorer**. If you click on 'Access now' button, the OECD Data Explorer screen, as in <Figure 2.1.20> will appear.



<Figure 2.1.20> OECD Data Explorer screen for life expectancy at birth

If you click on **Download** button, and then select **Table in Excel**, an Excel file of Life expectancy, OECD.ELS.HD,DSD_HEALTH_STAT@DF_LE,,filtered,2024-09-13 13-50-12.xlsx, is downloaded. If you open the Excel file, it looks like, as in <Figure 2.1.21>.

B	C	D	E	F	G	H	I	J	K	L
Life expectancy										
Frequency of observation: Annual										
Age: 0 years										
Unit of measure: Years										
Time period		2015	2016	2017	2018	2019	2020	2021	2022	2023
Reference area										
Measure: Life expectancy Sex: Total										
Australia		82.4	82.4	82.5	82.7	82.9	83.2	83.3	83.2	
Austria		81.3	81.8	81.7	81.8	82	81.3	81.3	81.4	81.6
Belgium		81.1	81.5	81.6	81.7	82.1	80.8	81.9	81.8	82.5
Canada		81.9	82	81.9	81.9	82.3	81.7	81.6		
Chile		79.8	80	80.2	80.4	80.6	80.8	P 81	P 81.2	
Colombia		75.4	75.7	75.9	76.5	76.6	76.7	76.8	76.9	
Costa Rica		79.9	80	80.2	80.3	80.5	80.6	80.8	80.9	
Czechia		78.7	79.1	79.1	79.1	79.3	78.2	77.2	79	80
Denmark		80.8	80.9	81.1	81	81.5	81.6	81.5	81.3	81.9
Estonia		78	78	78.4	78.5	79	78.9	77.2	78.1	78.8
Finland		81.6	81.5	81.7	81.8	82.1	82	81.9	81.2	81.7
France		82.4	82.7	82.7	82.8	83	82.3	82.4	82.3	83.1
Germany		80.7	81	81.1	81	81.3	81.1	80.8	80.7	
Greece		81.1	81.5	81.4	81.9	81.7	81.4	80.2	80.8	81.6
Hungary		75.7	76.2	76	76.2	76.5	75.7	74.3	76	76.9

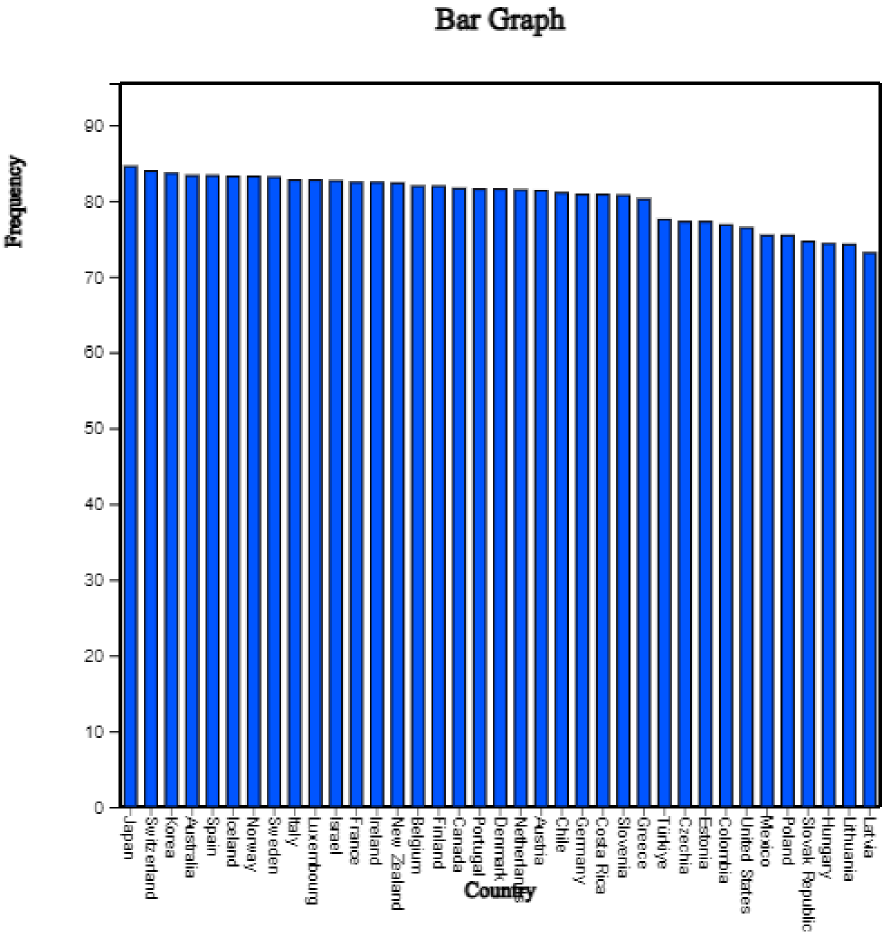
<Figure 2.1.21> Excel file of OECD life expectancy at birth

It includes Life expectations at birth for the total population, male and female population from the year 2015 to 2023. Since some of the data are missing in 2022 and 2023, let us draw graphs using only the data in 2021 for the total, female, and male population. The downloaded file is modified after removing missing data in U.K. as in <Figure 2.1.22> to make a file in CSV format and it is saved with a file name 'OECD_life_expectancy_at_birth_2021.csv'

	A	B	C	D
1	Country	Total	Female	Male
2	Australia	83.3	85.4	81.3
3	Austria	81.3	83.7	78.8
4	Belgium	81.9	84.3	79.4
5	Canada	81.6	84.0	79.3
6	Chile	81.0	83.8	78.3
7	Colombia	76.8	80.0	73.7
8	Costa Rica	80.8	83.3	78.2
9	Czechia	77.2	80.5	74.1
10	Denmark	81.5	83.3	79.6
11	Estonia	77.2	81.4	72.7
12	Finland	81.9	84.6	79.3
13	France	82.4	85.5	79.3
14	Germany	80.8	83.3	78.4
15	Greece	80.2	82.9	77.4
16	Hungary	74.3	77.8	70.7
17	Iceland	83.2	84.6	81.8
18	Ireland	82.4	84.3	80.5
19	Israel	82.6	84.6	80.5
20	Italy	82.7	84.9	80.5
21	Japan	84.5	87.6	81.5
22	Korea	83.6	86.6	80.6
23	Latvia	73.1	78.0	68.2
24	Lithuania	74.2	78.8	69.5
25	Luxembourg	82.7	84.8	80.5
26	Mexico	75.4	78.2	72.5
27	Netherlands	81.4	83.0	79.7
28	New Zealand	82.3	84.0	80.5
29	Norway	83.2	84.7	81.7
30	Poland	75.4	79.5	71.4
31	Portugal	81.5	84.4	78.5
32	Slovak	74.6	78.2	71.2
33	Slovenia	80.7	83.8	77.7
34	Spain	83.3	86.2	80.4
35	Sweden	83.1	84.9	81.3
36	Switzerland	83.9	85.8	81.8
37	Türkiye	77.5	80.3	74.8
38	United States	76.4	79.3	73.5

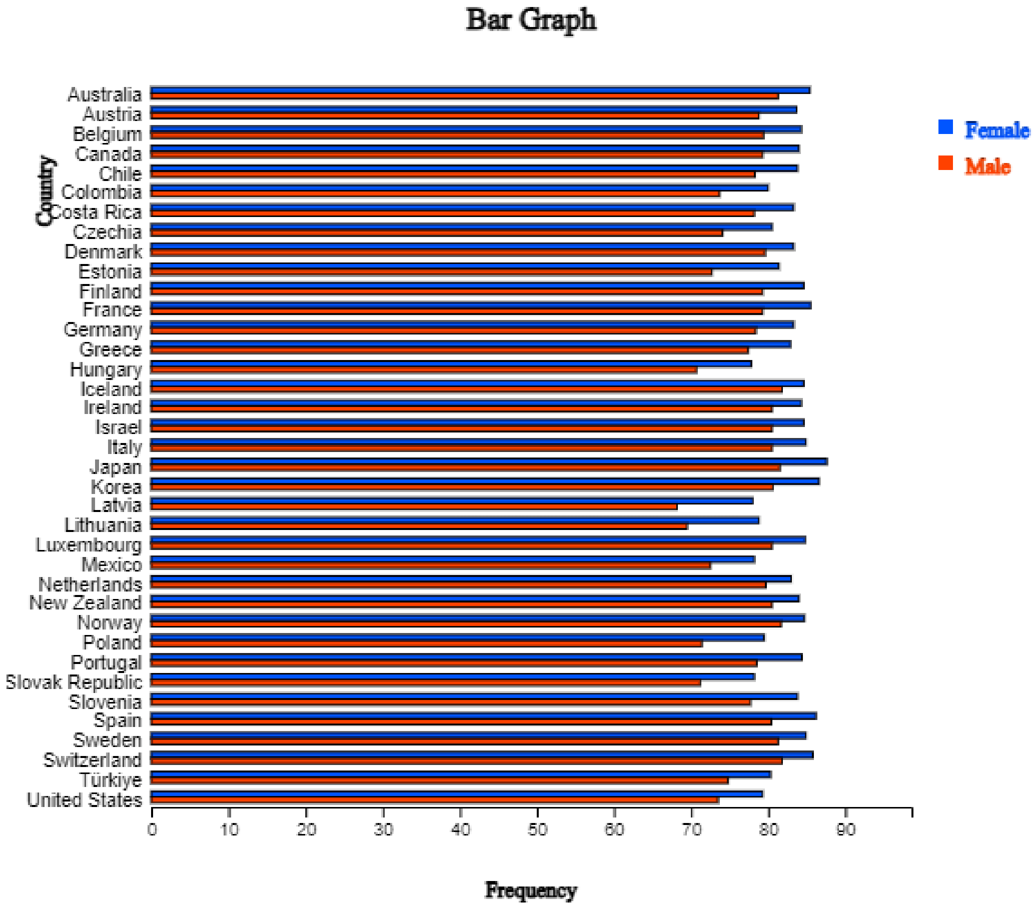
<Figure 2.1.22> Modified OECD file for data processing

If you load the file, OECD_life_expectancy_at_birth_2021.csv, to『eStat』system and select 'Analysis Var' as 'Country' and select 'by Group' as 'Total', a vertical bar graph will appear in the Graph window. To compare the life expectancy by country, select an option in Sorting as 'Descending' below the graph. A vertical bar graph sorted in descending order of life expectancy appears in <Figure 2.1.23>.



<Figure 2.1.23> Bar graph sorted in descending order of life expectancy

You can easily check that Japan has the highest life expectancy and Latvia has the lowest. If you click the variable names 'Country', ‘Female’ and ‘Male’ after erasing the current variable selection and clicking the horizontal 'Side-by-side' bar graph button, a bar graph, as in <Figure 2.1.24> appears in the Graph window. You can check the difference in life expectancy between female and male by country. Latvia has the largest discrepancy. If the characters of the country name are too small to see, you can enlarge the screen by holding the [Ctrl] key and rolling up the wheel mouse. You can click the horizontal bar graph icon above the Graph window to draw a horizontal bar graph as in <Figure 2.1.24>.



<Figure 2.1.24> Horizontal bar graph for life expectancy by country

Practice 2.1.2 (Alcohol Expenditure: OECD)

Draw a bar graph using the following data in 『eStat』 system and analyze the graph.

[Ex] ⇨ DataScience ⇨ OECD_AlcoholExpenditure_2013.csv

Practice 2.1.3 (Obesity Ratio: World)

Draw a bar graph using the following data in 『eStat』 system and analyze the graph.

[Ex] ⇨ DataScience ⇨ WORLD_ObesityRatio_Age15over__2017

Example 2.1.6 (Male and Female Population by Age Groups)
In 2015, the male and female populations by age groups in Korea are shown in Table 2.1.5. Using this data, draw a vertical bar graph by age group and find appropriate graphs to quickly analyze this data's characteristics.

Table 2.1.5 male and female populations by age group in Korea (KOSTAT Census 2015, unit 10,000 persons)

Age Interval	2015 Male	2015 Female
00 - 04	115	109
05 - 09	116	109
10 - 14	126	116
15 - 19	166	151
20 - 24	181	158
25 - 29	158	145
30 - 34	158	176
35 - 39	193	186
40 - 44	214	207
45 - 49	215	212
50 - 54	209	205
55 - 59	192	194
60 - 64	134	141
65 - 69	102	110
70 - 74	79	97
75 - 79	55	80
80 - 84	28	54
over 85	13	39

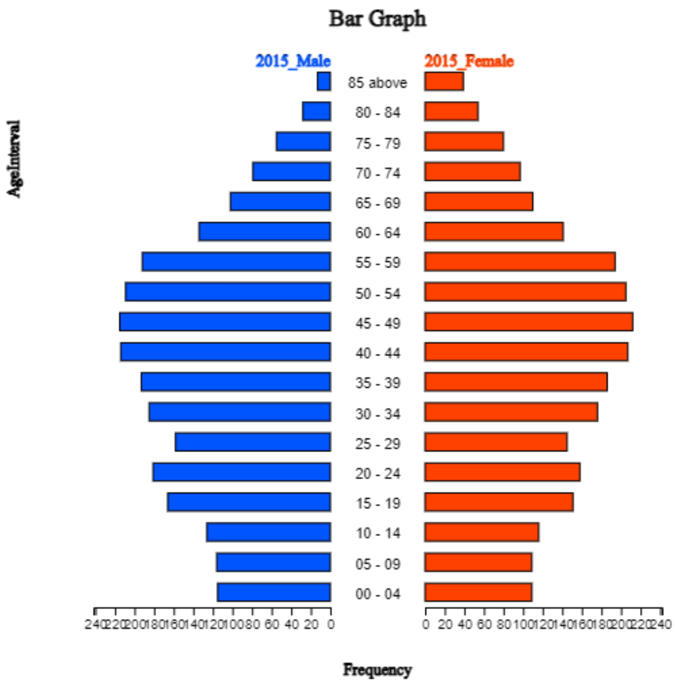
Answer

The data of Table 2.1.6 can be loaded from『eStat』using the following address.

[Ex] ⇨ DataScience ⇨ PopulationByGender.csv.

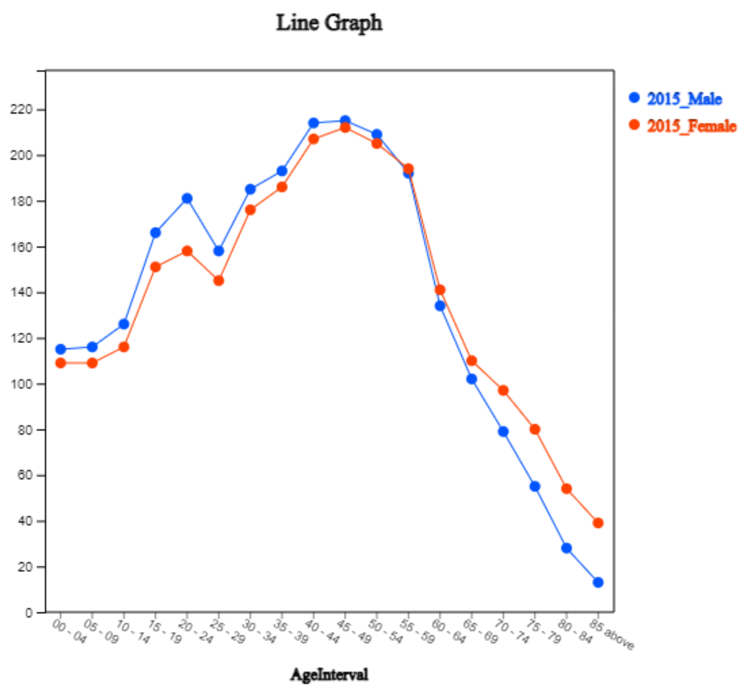
Click on the variable name of the first variable, 'AgeInterval' followed by the second variable ‘2015_Male’ and the third variable ‘2015_Female'. You may select the ’AgeInterval’ variable from the 'Analysis Var' box and ‘2015_Male' and ’2015_Female’ variables sequentially from the 'By Group box. When these variables are selected, a separate vertical bar graph which separates the male and female populations with the same scale of the Y-axis will appear in the Graph window.

Among ten possible bar graphs, a side-by-side bar graph would be useful because it shows the comparison of the number of male and female populations in each age interval. Or ratio bar graph which shows directly the proportions of male and female populations in each age interval can also be useful. In each of the graphs, you can easily see that the female population is getting larger than the male population after the age interval of 50s and more. An overall distribution of the male and female populations by age group can be observed by using a two-sided (bi-lateral) horizontal bar graph as in <Figure 2.1.25> usually called a population pyramid. Currently, Korea has an age-specific population structure that looks like a jar. In other words, the population in age intervals of 40 to 50 is higher than the population in age intervals of 30 or less, which is gradually decreasing. It would cause many problems in the future society such as a population decrease, a medicare budget increase, etc.



<Figure 2.1.25> Population pyramid (Bi-lateral graph of the population by age group and by gender

A line graph as in <Figure 2.1.26> can also be used to see this kind of pattern.



<Figure 2.1.26> Line graph of population by age and by gender

Practice 2.1.4 (Death rates in Virginia)

For each of five age groups (50–54, 55–59, 60–64, 65–69, 70–74), death rates are measured per 1000 population per year in Virginia. They are cross-classified by population group, such as Rural/Male, Rural/Female, Urban/Male and Urban/Female. These data are saved at the following location of 『eStat』system.

[Ex] ⇨ DataScience ⇨ VADeaths.csv

Draw appropriate graphs to analyze the characteristics of the data.

In general, if there are many groups (columns) on the frequency data, you can compare the difference between groups for each category of the analysis variable using different kinds of graphs. If there are many groups, it is recommended that you draw several kinds of graphs because each graph can show you different data characteristics.

If data are observed over time, it is called a time series, and a line graph is usually used to observe a trend over time. The X-axis includes values of a time variable, which are spaced equally, and the Y-axis represents a scale of all time series data. Each data pair, time and value, is marked as a point in a two-dimensional coordinate plane, and two adjacent points are connected with a line.

Practice 2.1.5 (Average Temperatures by Season in Korea)

Average temperatures of each season were observed from 1973 to 2016 in Korea, and data are saved at the following location of 『eStat』 system.

[Ex] ⇨ DataScience ⇨ Summary_TemperatureBySeason.csv

Draw a line graph of the temperatures by season and observe their characteristics.

2.1.3 Visualization of text data

A word cloud is a visual representation of text data. It visualizes the word frequency in a given text as a weighted list. The importance of each word is shown in the word cloud by font size or color. Bigger term means greater weight. The word cloud is useful for quickly perceiving the most prominent words to determine their relative prominence. Recently, it has been used to visualize the topical content of political speeches. It can be used as a website navigation aid to determine hyperlinks to items associated with the words in social software. The keyword in the cloud is sometimes used as a search engine marketing term that refers to a group of keywords relevant to a specific website. Many algorithms generate a word cloud. 『eStat』 adopted the algorithm of d3 open software. There are evolving approaches to constructing a word cloud by applying word co-occurrences in documents.

Example 2.1.9 (Word Cloud)
Generate a word cloud on the following description on data science and analyze important words.

> The development of these technologies has created massive data, called 'Big Data', that was unimaginable in the past. Typical examples of big data include data from Google's search records, social media messages by mobile phones, weblogs by internet connections, and telephone records of global telecom companies. The big data are expected to grow and increase exponentially in the future, and hyper-forecasting is also expected to be possible. The success or failure of each individual, group, company and even country depend on how to utilize big data efficiently.
>
> The analysis of big data that emerged this century is so enormous and diverse in the amount of data that it can not be fully utilized just by traditional statistical approaches. To analyze and utilize big data, we must apply theories of statistics, computer science, mathematics, management. or related disciplines simultaneously. Data science is a new area of study in which statistics, mathematics, computer science and other disciplines are fused to analyze and utilize big data, which emerged this century.

Answer

Click the eStaU icon and click [Word Cloud] in the menu, or you can use the QR code below.
Copy the sample text to [Data Input] text area and click [Execute] button. Then, a word cloud on data science is drawn.
'Data' is the highest frequency word in the word cloud,'big' is the next in this word cloud.

[Word Cloud]

Word Cloud

[Data Input] Erase Data

```
The development of these technologies has created massive data, simply called â€Big Dataâ€
were unimaginable in the past. Typical examples of the big data include data from Google's
records, social media messages by mobile phones, web logs by internet connections, and tele
records of global telecom companies. The big data are expected to grow and increase exponen
in the future and the hyper-forecasting is also expected to be possible. The success or fai
each individual, group, company and even country would depend on how to utilize the big dat
efficiently. The analysis of the big data that emerged this century is so enormous and dive
the amount of data that can not be fully utilized just by traditional statistical approache
the analysis and utilization of the big data, theories of statistics, computer science,
mathematics, management or related disciplines must also be applied simultaneously. Data Sc
```

Execute

Graph Save

Practice 2.1.6 (Inaugural Address of US President: Jonh F. Kennedy))

Generate a word cloud on the following part of the inaugural address by US President John F. Kennedy and analyze important words.

In the long history of the world, only a few generations have been granted the role of defending freedom in its hour of maximum danger. I do not shrink from this responsibility--I welcome it. I do not believe that any of us would exchange places with any other people or any other generation. The energy, the faith, and the devotion which we bring to this endeavor will light our country and all who serve it--and the glow from that fire can truly light the world.
And so, my fellow Americans: ask not what your country can do for you--ask what you can do for your country.
My fellow citizens of the world: ask not what America will do for you, but what together we can do for the freedom of man.

2.2 Visualization of quantitative data

Visualizing the quantitative data is a basic statistical analysis step, an exploratory data analysis before you get into some statistical analysis. Based on this exploratory analysis, you can apply an estimation for a single population parameter in section 4.4, a testing hypothesis for two populations in section 5.2, and a testing hypothesis for several populations in section 5.3. We can also apply a regression analysis for two quantitative variables in section 5.4.

2.2.1 Visualization of a single quantitative variable

In the case of the quantitative data, raw data are directly used to visualize the data. Visualization of the quantitative data is discussed by separating cases of the data without group and with group. In this section, we introduce visualization of the quantitative data by separating cases of the data without group and with group.

Visualization of a single quantitative variable without a group variable

Data such as height and weight, whose possible values are real numbers, are called quantitative data. To visualize the quantitative data of a variable, dot graph, histogram, stem and leaf plot are used. To visualize the quantitative data of two variables, a scatter plot that utilizes a two-dimensional coordinates is used.

A dot graph is used to visualize the quantitative data with fewer data counts. To draw the dot graph, we first draw the horizontal line and set its scale so that all data can be displayed on the horizontal line by considering the minimum and maximum of the data, then mark each data value in the dot corresponding to its scale. The dot graph makes it easy to see distribution patterns and anomalies in the data.

If there are too many observations of the quantitative data and too many possible data values, the dot graph may not have enough space to show all the data. In such cases, we divide all possible data values into several intervals, and count the number of data belonging to each interval. Using the frequencies of each interval, we draw a histogram similar to the bar graph with no spacing between bars. You might ask, 'How many intervals do I need to have?' There is no exact answer for the number of intervals, but 5 ± 2 number of intervals is usually used when there is a small number of data. A square root of the number of data is also often used as the number of intervals, but if the number of intervals is too many, it is not easy to analyze the data sometimes. As far as the number of intervals is concerned, it depends on the analyst's judgment.

A stem and leaf plot is a variation of the histogram recently used to visualize the quantitative data. The stem and leaf plot can quickly tell the range of observations, shape of distribution, and concentration. The name shows the data in the form of stems and leaves by considering the digits of data values: For each number in the data, we first investigate where it belongs to a stem and then write down the last digit of the number as a leaf corresponding to the stem. After investigating all numbers in the data, we rearrange the values of the leaves on each stem in ascending order. The stem and leaf plot has been commonly used in recent years as both an interval-specific frequency distribution and a histogram for the quantitative data.

A scatter plot is to visualize data of two quantitative variables using two-dimensional coordinates. The scatter plot can be considered as an extension of the dot graph for the single quantitative variable. Each pair of the data of two quantitative variables is expressed as a dot with one value on the X-axis and the other value on the Y-axis in the XY plane. We can observe the relationship between two quantitative variables efficiently using the scatter plot.

If the quantitative data are the sample data from a population, visualization of this sample data is used as a basic exploratory data analysis for estimation and testing hypothesis.

Example 2.2.1 (Otter Length)
The following data show the lengths of 30 otters. Use『eStat』to draw a dot graph, a histogram, a stem and leaf plot. (unit cm)

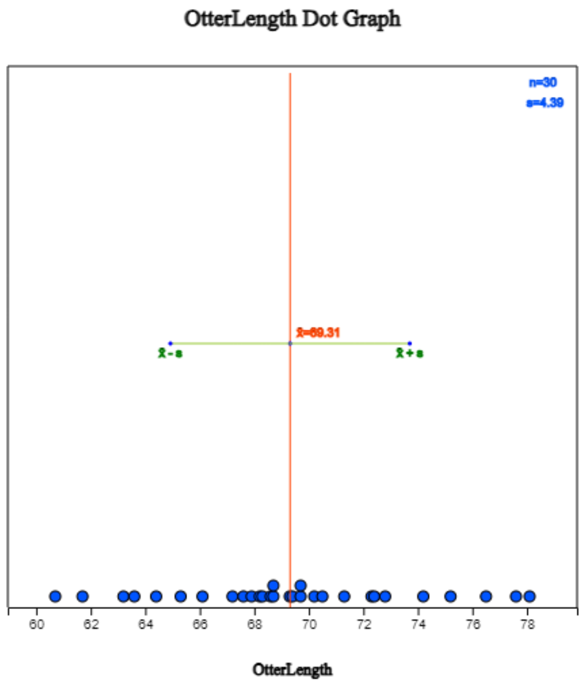
63.2 65.3 67.6 68.7 69.7 60.7 72.4 75.2 64.4 76.5
68.3 69.3 70.2 71.3 74.2 63.6 66.1 67.9 68.7 70.5
72.3 72.8 77.6 78.1 69.7 69.4 68.6 68.2 67.2 61.7

Answer

Enter all 30 data into V1 column of the sheet in『eStat』system and specify the variable name of V1 as 'OtterLength'. This data can also be found at the following location

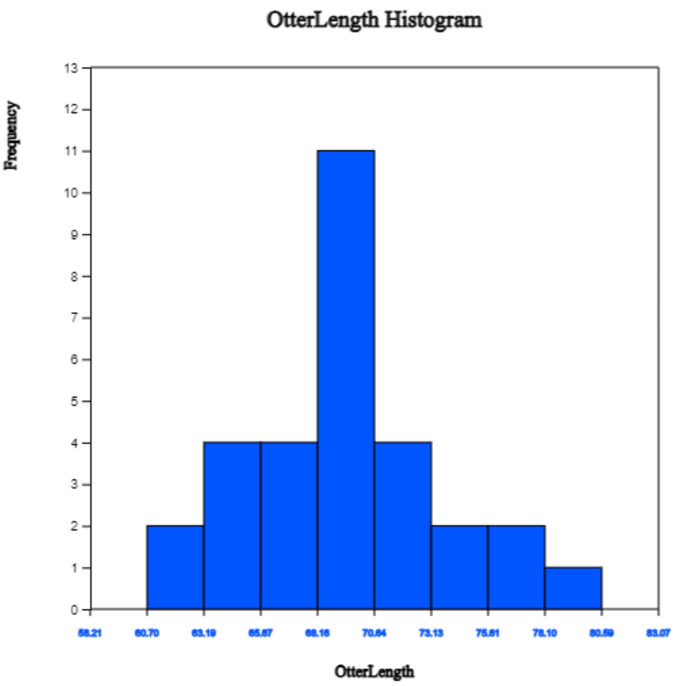
[Ex] ⇨ DataScience ⇨OtterLength.csv

Click on the dot graph icon . Click the variable name, 'OtterLength', then a dot graph of the otter length will appear in the Graph window as in <Figure 2.2.1>. You can also select 'OtterLength' variable in the selection box of the Analysis Variable. Checking the 'Mean/Std Dev' in the options window below the graph shows the average of the data and the (average) ± (one standard deviation) interval as in <Figure 2.2.1>. We can observe that a large number of data can be found around the average, and the data are distributed symmetrically around the average.

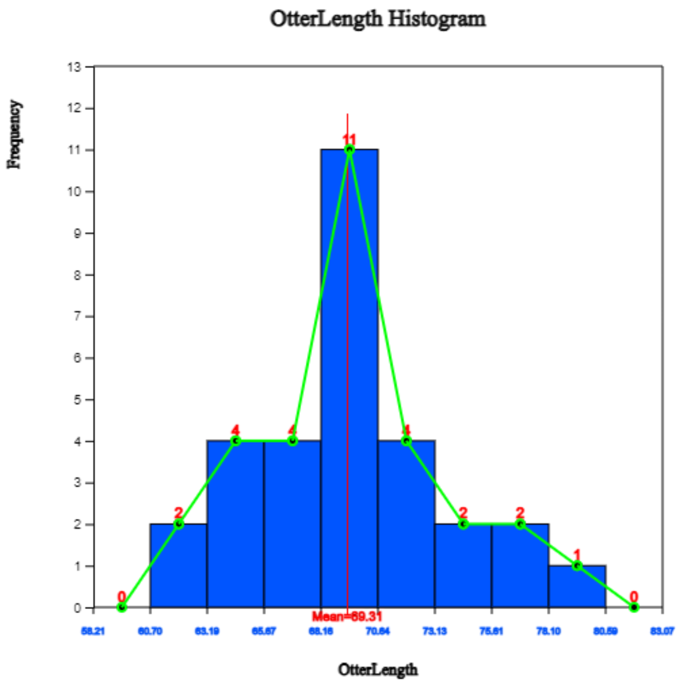


<Figure 2.2.1> Dot graph of otter lengths with Mean/StdDev interval

Click on the histogram icon to display the graph as in <Figure 2.2.2>. If you check the options of ‘Mean’, ‘Frequency’ and ‘Frequency Polygon’ below the graph, the histogram is changed as in <Figure 2.2.3>. You can also observe that there are large amounts of data near the mean, and the data are distributed in almost symmetrical form around the mean.



<Figure 2.2.2> Histogram of otter length



<Figure 2.2.3> Histogram polygon of otter lengths with mean, frequency and polygon

Click on the [Frequency Table] button in the options window below the graph to output a frequency table by intervals based on the histogram currently drawn in the Log Area as in <Figure 2.2.4>.

Histogram Frequency Table	Group Name	0
Interval (OtterLength)		Total
1 : [60.70, 63.19) Row % Col % Tot %	2 100.0% 6.7% 6.7%	2 100.0% 6.7%
2 : [63.19, 65.67) Row % Col % Tot %	4 100.0% 13.3% 13.3%	4 100.0% 13.3%
3 : [65.67, 68.16) Row % Col % Tot %	4 100.0% 13.3% 13.3%	4 100.0% 13.3%
4 : [68.16, 70.64) Row % Col % Tot %	11 100.0% 36.7% 36.7%	11 100.0% 36.7%
5 : [70.64, 73.13) Row % Col % Tot %	4 100.0% 13.3% 13.3%	4 100.0% 13.3%
6 : [73.13, 75.61) Row % Col % Tot %	2 100.0% 6.7% 6.7%	2 100.0% 6.7%
7 : [75.61, 78.10) Row % Col % Tot %	2 100.0% 6.7% 6.7%	2 100.0% 6.7%
8 : [78.10, 80.59) Row % Col % Tot %	1 100.0% 3.3% 3.3%	1 100.0% 3.3%
Total	30 100.0% 100.0%	30 100.0%

<Figure 2.2.4> Frequency table of the histogram

The number and the width of the intervals in the histogram are automatically calculated by 『eStat』 system, but you can redraw them by specifying the 'Interval Start' and 'Interval Width' from the option below the graph and then clicking [Execute New Interval] button.

Click on the stem and leaf plot icon to display the graph shown in <Figure 2.2.5>. This graph is a variant of the histogram where intervals are [60, 61), [61, 62), ... , [78, 79). After finding the number of data belonging to each interval, the digits of 60, 61, ... , 78 become the stem of the graph and the last digits of all data values belonging to each interval become the leaves of each stem. The leaves (last digits) of each stem are sorted in ascending order from small to large.

OtterLength Stem and Leaf Plot

Stem	Leaf
60	7
61	7
62	
63	26
64	4
65	3
66	1
67	269
68	23677
69	3477
70	25
71	3
72	348
73	
74	2
75	2
76	5
77	6
78	1

<Figure 2.2.5> Stem and leaf plot of otter length

Practice 2.2.1 (Bicycle Road in Seoul)
The following data are the lengths of bike-only roads in Seoul's 25 administrative districts as of 2016. Use『eStat』to draw a dot graph, a histogram, a stem and leaf plot. Analyze the graphs.

0.0 0.0 1.5 0.6 0.0 1.4 3.1 0.3 0.1 0.7 0.8 0.0 0.4 2.8 16.1
8.1 1.5 3.8 4.6 0.0 2.9 0.0 4.4 18.4 3.3
(unit km, Seoul City information system, 2016)

Saved at [Ex] ⇨ DataScience ⇨ BikeRoad.csv

Practice 2.2.2 (Lengths of Major North American Rivers)
The lengths (in miles) of 141 major rivers in North America compiled by the US Ecological Survey are saved at the following location of『eStat』.

[Ex] ⇨ DataScience ⇨ rivers.csv

Use『eStat』to draw a dot graph, a histogram, a stem and leaf plot. Analyze the graphs.

Practice 2.2.3 (Annual Precipitation in US Cities)
The average amount of precipitation (rainfall) in inches for each of 70 United States (and Puerto Rico) cities is saved at the following location of 『eStat』.

[Ex] ⇨ DataScience ⇨ Precip.csv

Use『eStat』to draw a dot graph, a histogram, a stem and leaf plot. Analyze the graphs.

Visualization of a single quantitative variable with a group variable

If you can visualize the quantitative data by several groups using the same scale, comparing the characteristics of groups is easy. Suppose the data are the sample data from two or more populations (groups). In that case, this comparison by visualization can be used as a basic exploratory data analysis for a testing hypothesis in Chapter 5.

Example 2.2.2 (Teacher's Age by Gender)
In a middle school, the age and gender of all teachers are surveyed. The data are saved at the following location of 『eStat』.

[Ex] ⇨ DataScience ⇨ TeacherAgeByGender.csv.

Using this data, draw a dot graph, a histogram, a stem and leaf plot of the age by gender.

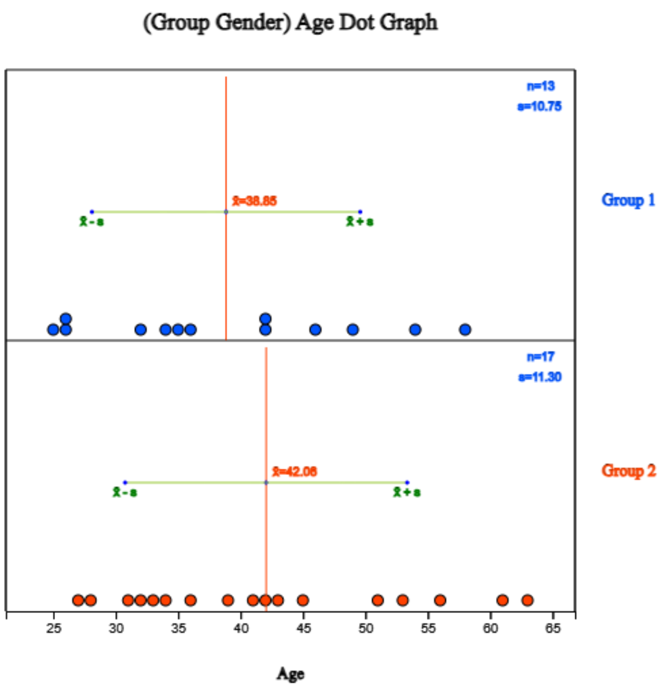
Answer

Select the file from 『eStat』 by clicking

[Ex] ⇨ DataScience ⇨ TeacherAgeByGender.csv.

or scan the QR.

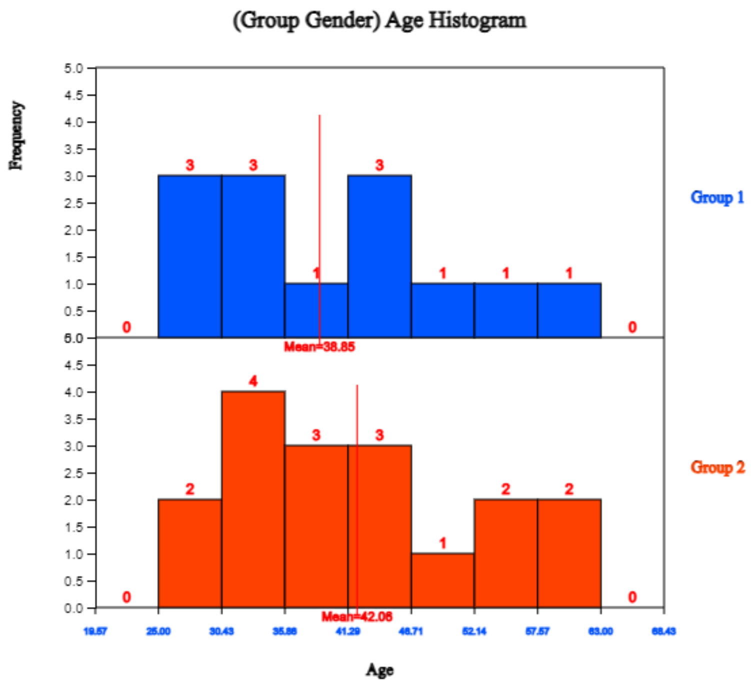
Click on the dot graph icon and click the variable names 'age' and 'gender' to draw the dot graph of the age by gender as in <Figure 2.2.6>. You can select ‘Age’ from the selection box of 'Analysis Var' and ‘Gender’ from the selection box of ‘By Group’ variable. By checking the 'Mean/StdDev’ in the options window below the graph, the mean line and (average) ± (one standard deviation) intervals are shown on the graph.



<Figure 2.2.6> Dot graph of the age by gender with interval of mean / std dev

Looking at the dot graph in <Figure 2.2.6>, the average age of female teachers is higher than that of male teachers. We can apply statistical analysis, such as a testing hypothesis, to compare two population means if these data are samples from two populations. It will be discussed in Chapter 5.

If you click on the histogram icon , the histogram as in <Figure 2.2.7> appears in the Graph window. You can draw the mean lines, frequencies, and frequency polygons on the histogram by checking the options below the graph. If you click [Frequency Table] button, the frequency table of the histogram can be displayed in the Log Area. 『eStat』 calculates the number and the width of the intervals automatically, but you can redraw them by specifying the ‘Interval Start’ and ‘Interval Width’ in the options window below the graph.



<Figure 2.2.7> Histogram of age by gender: Group 1 is for male and Group 2 for female

If you click on the stem and leaf plot icon , the graph as in <Figure 2.2.8> will be displayed in the Graph window. This stem and leaf plot is a variant of the histogram in which the age data are divided into intervals as [20, 30), [30, 40), ... [60,70) by using the possible decimal digits of 10s as the stem. The age data belonging to each interval are investigated and displayed using the age's last digit as the leaf. The last digits (leaf) of the age are sorted in ascending order from small to large. In the case of two groups, a bi-lateral stem and leaf plot as in <Figure 2.2.9> can be drawn by clicking on the bi-lateral stem and leaf icon .

(Group Gender) Age Stem and Leaf Plot

Stem	Group 1 Leaf
2	566
3	2456
4	2269
5	48
6	

Stem	Group 2 Leaf
2	78
3	123469
4	1235
5	136
6	13

<Figure 2.2.8> Stem and leaf plot of age by sex

(Group Gender) Age Stem and Leaf Plot

Group 1 Leaf	Stem	Group 2 Leaf
665	2	78
6542	3	123469
9622	4	1235
84	5	136
	6	13

<Figure 2.2.9> Bi-lateral stem and leaf plot of age by sex

Practice 2.2.4 (Oral Cleanliness by Brushing Methods)
According to the brushing method (1:basic method, 2: rotation method), oral cleanliness scores are examined and stored at the following location of『eStat』.

[Ex] ⇨ DataScience ⇨ ToothCleanByBrushMethod.csv.

Using 『eStat』 , draw a dot graph, a histogram, a stem and leaf plot of oral cleanliness by brushing.

Practice 2.2.5 (Plant Growth by Condition)
Results from an experiment to compare yields (as measured by the dried weight of plants) are obtained under control (leveled 'ctrl') and two different treatment conditions (leveled 'trt1' and 'trt2'). The weights data with 30 observations on each control and two treatments ('crtl', 'trt1', 'trt2') are saved at the following location of 『eStat』.

[Ex] ⇨ DataScience ⇨ PlantGrowth.csv

Use 『eStat』 to draw a dot graph, a histogram, a stem and leaf plot of the weights by three groups.

Practice 2.2.6 (Effectiveness of Insect Sprays)
The counts of insects in agricultural experimental units were treated with six different insecticides. Data with 72 observations on 2 variables, insect count and sprays (A, B, C, D, E, F), are saved at the following location of 『eStat』. (Source: Beall, G., (1942) The Transformation of data from entomological field experiments, Biometrika, 29, 243–262.)

[Ex] ⇨ DataScience ⇨ InsectSprays.csv

Use 『eStat』 to draw a dot graph, a histogram, a stem and leaf plot of the insect counts by the types of sprays.

2.2.2 Visualization of two or more quantitative variables

In general, we investigate several characteristics from one subject or one observation. For example, when we investigate students in an elementary school, we examine their gender, height, and weight simultaneously, which are one categorical and two quantitative variables.

If you have data on two quantitative variables, we can use a scatter plot to analyze the data. A scatter plot displays the data on a two-dimensional plane with values for one variable being the X-axis and values for the other being the Y-axis. If a categorical variable such as gender is also collected together, we can draw a scatter plot by differentiating the colors of the dots by gender. If data are a sample from a population, we can use the scatter plot to analyze correlation and regression.

If you have data on several quantitative variables and qualitative variables, we can use a scatter plot matrix to analyze a relation between quantitative variables.

Visualization of two quantitative variables

Example 2.2.3 (Height and Weight by Gender)
Data on gender, height, and weight of 10 elementary school students are saved at the following location of 『eStat』.

[Ex] ⇨ DataScience ⇨ HeightWeightByGender.csv.

1) Draw a scatter plot of height and weight using 『eStat』.
2) Draw a scatter plot of height and weight by gender using 『eStat』.

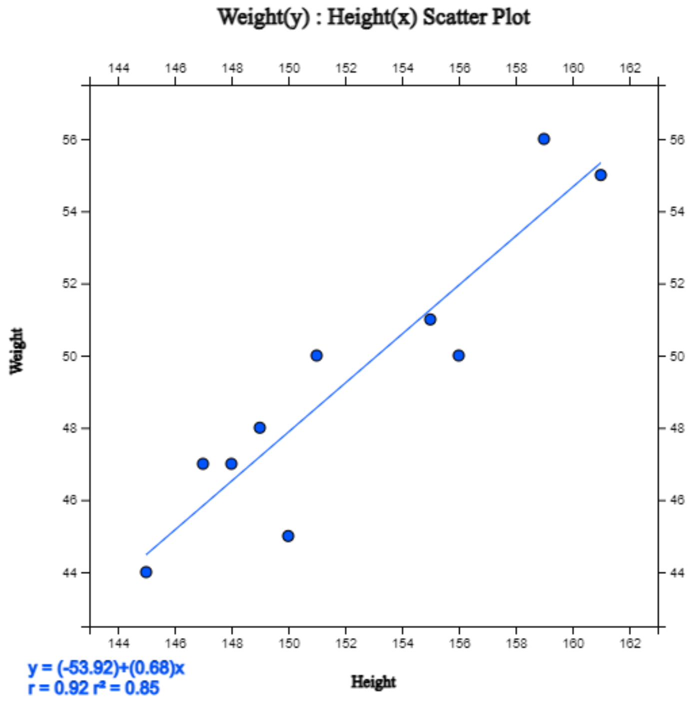
Answer

Retrieve the file from 『eStat』 by clicking

[Ex] ⇨ DataScience ⇨ HeightWeightByGender.csv.

or scan the QR on the left.

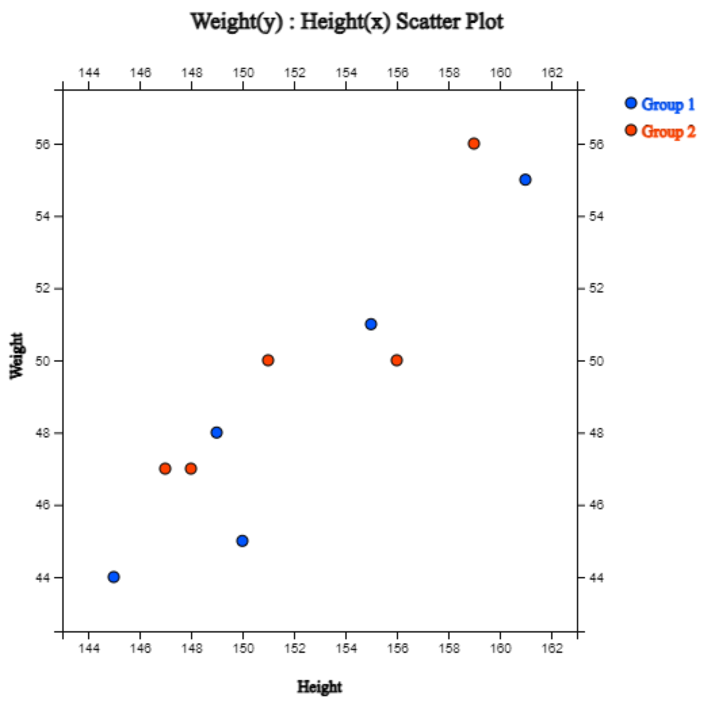
Clicking on the scatter plot icon and clicking on the 'weight' and 'height' variable names, a scatter plot with the weight on the Y-axis (the first selected variable) and the height on the X-axis (the second selected variable) will appear in the Graph window as in <Figure 2.2.10>. You can also select 'weight' in the 'Y-variable' selection box and 'height in the 'by X-variable' selection box.



<Figure 2.2.10> Scatter plot of height and weight with a regression line

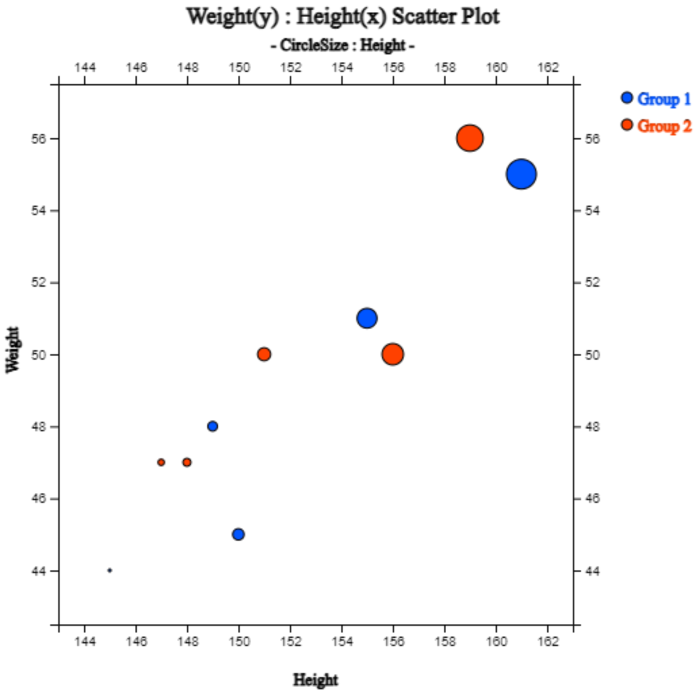
Checking the 'Regression' in the options window below the graph, a scatter plot with a regression line appears. This regression line indicates a relationship between weight and height. If you look at the scatter plot, you can see that the larger the height, the heavier the weight is. See Chapter 4 for more discussion on the regression analysis.

To draw a scatter plot by gender, select 'Gender' in the 'Group' box of options. It shows a scatter plot with different colors depending on the gender as in <Figure 2.2.11>. Checking the 'Regression' in the options will show the regression lines for each gender.



<Figure 2.2.11> Scatter plot of height and weight by gender groups

If you select the height as a 'Size Var' in the option, the dots in the scatter plot are proportional to the height as in <Figure 2.2.12>.



<Figure 2.2.12> Scatter plot of height and weight by gender with size variable of height

Practice 2.2.7 (Old Faithful Geiser)
Waiting time between eruptions and the eruption duration for the Old Faithful geyser in Yellowstone National Park, Wyoming, USA were collected. There are 272 observations on 2 variables, time between eruptions (in seconds) and waiting time for next eruption (in mins). The data are saved at the following location of 『eStat』.

[Ex] ⇨ DataScience ⇨ Faithful.csv
(Source: Applied Statistics, 39, 357-365. doi: 10.2307/2347385)

Draw a scatter plot of the time between eruptions and the waiting time for the next eruption.

Practice 2.2.8 (Age and Income by Gender)
A survey of age, monthly income, and gender (1: man, 2: woman) was conducted,

and the data are saved at the following location of 『eStat』.

[Ex] ⇨ DataScience ⇨ IncomeAge.csv.

Draw a scatter plot of the age and the monthly income by gender.

Visualization of several quantitative variables

If there are two or more quantitative variables, we can use a **scatter plot matrix** to visualize data. Suppose there are m number of quantitative variables. In that case, we can use $m \times m$ matrix of scatter plots using combinations of all quantitative variables in each column and row of the matrix. A histogram of each quantitative variable is drawn at the matrix's diagonal element with the same variable named row and column. A qualitative variable can be used as a group variable in the scatter plot matrix to visualize each data with different colors depending on its group value. The scatter plot matrix is useful for checking the relation between quantitative variables and is used for correlation and regression analysis.

A **parallel coordinate plot** (parallel graph) is an effective way to observe multiple quantitative variables and find out their relationships simultaneously. We create as many parallel coordinate lines as the number of variables, mark the values of each variable as points on the corresponding coordinate lines, and then connect them with lines. A qualitative variable can be used as a group variable in the parallel coordinate plot to visualize each line (data) with different colors depending on its group value.

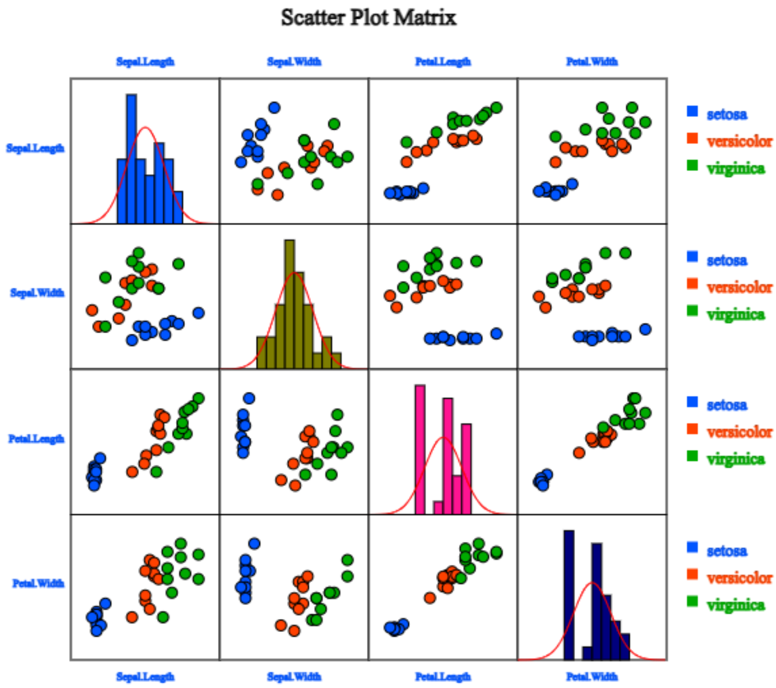
Example 2.2.4 (Scatter plot matrix)
Draw a scatter plot matrix and a parallel coordinate plot using four variables Sepal.Length, Sepal.Width, Petal.Length, Petal.Width, and Species is the group variable in Table 2.2.1. The data is saved in 『eStat』 system at Ex -> /DataScience/Iris30.csv.

Table 2.2.1 Iris data					
id	**Sepal.Length**	**Sepal.Width**	**Petal.Length**	**Petal.Width**	**Species**
1	5.1	3.5	1.4	0.2	setosa
2	4.9	3.0	1.4	0.2	setosa
3	4.7	3.2	1.3	0.2	setosa

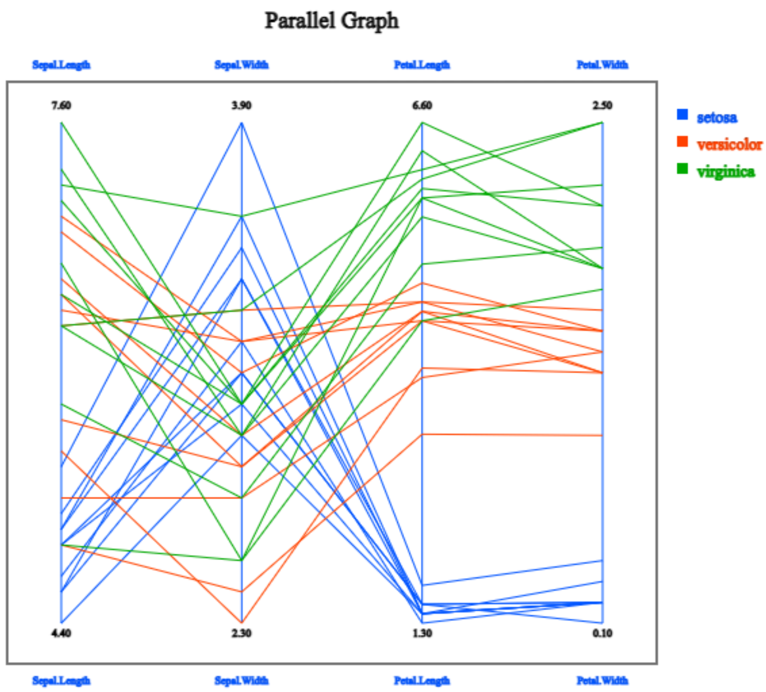
4	4.6	3.1	1.5	0.2	setosa
5	5.0	3.6	1.4	0.2	setosa
6	5.4	3.9	1.7	0.4	setosa
7	4.6	3.4	1.4	0.3	setosa
8	5.0	3.4	1.5	0.2	setosa
9	4.4	2.9	1.4	0.2	setosa
10	4.9	3.1	1.5	0.1	setosa
11	7.0	3.2	4.7	1.4	versicolor
12	6.4	3.2	4.5	1.5	versicolor
13	6.9	3.1	4.9	1.5	versicolor
14	5.5	2.3	4.0	1.3	versicolor
15	6.5	2.8	4.6	1.5	versicolor
16	5.7	2.8	4.5	1.3	versicolor
17	6.3	3.3	4.7	1.6	versicolor
18	4.9	2.4	3.3	1.0	versicolor
19	6.6	2.9	4.6	1.3	versicolor
20	5.2	2.7	3.9	1.4	versicolor
21	6.3	3.3	6.0	2.5	virginica
22	5.8	2.7	5.1	1.9	virginica
23	7.1	3.0	5.9	2.1	virginica
24	6.3	2.9	5.6	1.8	virginica
25	6.5	3.0	5.8	2.2	virginica
26	7.6	3.0	6.6	2.1	virginica
27	4.9	2.5	4.5	1.7	virginica
28	7.3	2.9	6.3	1.8	virginica
29	6.7	2.5	5.8	1.8	virginica
30	7.2	3.6	6.1	2.5	virginica

Answer

After you load the data file of Table 2.2.1, /DataScience/Iris30.csv, click the scatter plot matrix icon . Click 'Species' as the 'Group' variable and select 'Sepal.Length', 'Sepal.Width', 'Petal.Length', 'Petal.Width' as the 'Analysis Var'. Then the scatter plot matrix, as in <Figure 2.2.13>, will appear in the graph window. If you click the 'Parallel Graph' button below the graph, the parallel coordinate plot will appear as in <Figure 2.2.14>. If you click the 'Multivariate Stat' button below the graph, then basic statistics, covariances and correlations on four quantitative variables of each group will appear in the Log table window as in <Figure 2.2.15>.



<Figure 2.2.13> Scatter plot matrix using the data in Table 2.2.1



<Figure 2.2.14> Parallel graph using the data in Table 2.2.1

Mean (Std Dev)	Observation	Sepal.Length	Sepal.Width	Petal.Length	Petal.Width
Group 1 Species : setosa	10	4.860 (0.291)	3.310 (0.307)	1.450 (0.108)	0.220 (0.079)
Group 2 Species : versicolor	10	6.100 (0.727)	2.870 (0.340)	4.370 (0.488)	1.380 (0.169)
Group 3 Species : virginica	10	6.570 (0.804)	2.940 (0.337)	5.770 (0.600)	2.040 (0.291)
Total	30	5.843 (0.982)	3.040 (0.611)	3.863 (1.372)	1.213 (0.888)

Covariance Group 1 : setosa	Sepal.Length	Sepal.Width	Petal.Length	Petal.Width
Sepal.Length	0.085	0.070	0.019	0.009
Sepal.Width	0.070	0.094	0.017	0.016
Petal.Length	0.019	0.017	0.012	0.004
Petal.Width	0.009	0.016	0.004	0.006
Covariance Group 2 : versicolor	Sepal.Length	Sepal.Width	Petal.Length	Petal.Width
Sepal.Length	0.529	0.193	0.323	0.080
Sepal.Width	0.193	0.116	0.132	0.043
Petal.Length	0.323	0.132	0.238	0.065
Petal.Width	0.080	0.043	0.065	0.028

<Figure 2.2.15> Multivariate statistics using four quantitative variales in Table 2.2.1

You can practice scatter plot matrix, parallel coordinate plot and multivariate statistics using the module in『eStatU』, 'Ch 2 Scatter Plot Matrix' as following example.

[Scatter Plot Matrix and Parallel Coordinate Plot]

Scatter Plot Matrix - Parallel Graph - Multivariate Stat

Menu

Variable Name		Data Input
Y	Species	setosa,setosa,setosa,setosa,setosa,setosa,setosa,setosa,setosa,setosa,setosa,se
X_1	Sepal.Length	5.1,4.9,4.7,4.6,5,5.4,4.6,5,4.4,4.9,5.4,4.8,4.8,4.3,5.8,5.7,5.4,5.1,5.7,5.1,5.4,5.1,4.6
X_2	Sepal.Width	3.5,3,3.2,3.1,3.6,3.9,3.4,3.4,2.9,3.1,3.7,3.4,3,3,4,4.4,3.9,3.5,3.8,3.8,3.4,3.7,3.6,3.3
X_3	Petal.Length	1.4,1.4,1.3,1.5,1.4,1.7,1.4,1.5,1.4,1.5,1.5,1.6,1.4,1.1,1.2,1.5,1.3,1.4,1.7,1.5,1.7,1.5
X_4	Petal.Width	0.2,0.2,0.2,0.2,0.2,0.4,0.3,0.2,0.2,0.1,0.2,0.2,0.1,0.1,0.2,0.4,0.4,0.3,0.3,0.3,0.2,0.4
X_5		

Execute | Scatter Plot Matrix | Parallel Graph | Erase Data

Multivariate Stat | Graph Save | Table Save

2.3 R and Python practice

R Practice

Let us practice R commands using the data saved at C:\Rwork\PurchaseByCredit40.csv. The file format is a comma-separated value (csv) type. You can find this file from 『eStat』 system. Click Ex > DataScience and then click the data 'PurchaseByCredit40.csv'. After this file is loaded to 『eStat』, save it using 'csv Save' button. It will be saved in the Download folder on your PC. Copy this file to C:\Rwork\ folder.

You need to change first the working directory of R to use this data as follows.

File > Change Directory > C: > Rwork

# read the data file	
> card <- read.csv("PurchaseByCredit40.csv", header=TRUE, as.is=FALSE)	copy r command

> card

```
      id Gender Age Income Credit Purchase
1      1   male 20s LT2000   Fair      Yes
2      2 female 30s GE2000   Good       No
3      3 female 20s GE2000   Fair       No
4      4 female 20s GE2000   Fair      Yes
5      5 female 20s LT2000    Bad       No
6      6 female 30s GE2000   Fair       No
7      7 female 30s GE2000   Good      Yes
8      8   male 20s LT2000   Fair       No
9      9 female 20s GE2000   Good       No
10    10   male 30s GE2000   Fair      Yes
11    11 female 30s GE2000   Good      Yes
12    12 female 20s LT2000   Fair       No
13    13   male 30s GE2000   Fair       No
14    14   male 30s LT2000   Fair      Yes
15    15 female 30s GE2000   Good      Yes
16    16 female 30s GE2000   Fair       No
17    17 female 20s GE2000    Bad       No
18    18   male 20s GE2000    Bad       No
19    19   male 30s GE2000   Good      Yes
20    20   male 20s LT2000   Fair       No
21    21   male 20s LT2000   Fair      Yes
22    22 female 30s GE2000   Good       No
23    23 female 20s GE2000   Fair       No
24    24 female 20s GE2000   Fair      Yes
25    25 female 20s LT2000    Bad       No
26    26 female 30s GE2000   Fair       No
27    27 female 30s GE2000   Good      Yes
28    28   male 20s LT2000   Fair       No
29    29 female 20s GE2000   Good       No
30    30   male 30s GE2000   Fair      Yes
31    31 female 30s GE2000   Good      Yes
32    32 female 20s LT2000   Fair       No
33    33   male 30s GE2000   Fair       No
34    34   male 30s LT2000   Fair      Yes
35    35 female 30s GE2000   Good      Yes
36    36 female 30s GE2000   Fair       No
37    37 female 20s GE2000    Bad       No
38    38   male 20s GE2000    Bad       No
39    39   male 30s GE2000   Good      Yes
40    40   male 20s LT2000   Fair       No
```

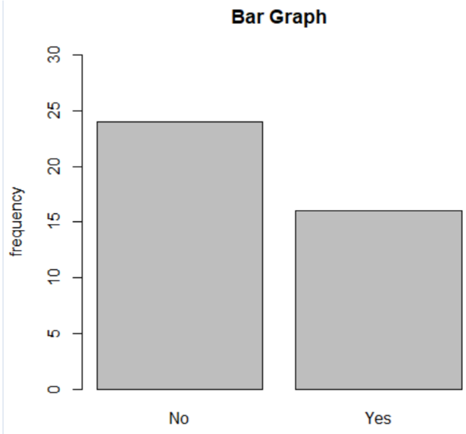
> attach(card)

copy r command

Bar graph

> plot(Purchase, main="Bar Graph", ylab="frequency", ylim=c(0,30))

copy r command



Pie chart

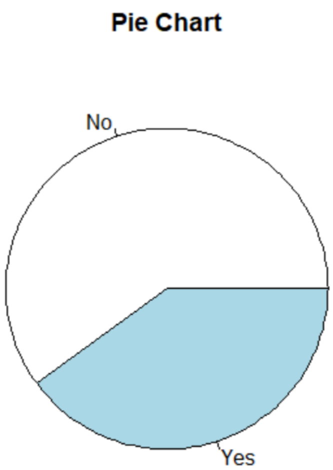
> freq <- table(Purchase)

copy r command

```
 freq
Purchase
 No Yes
 24  16
```

> pie(freq, main="Pie Chart")

copy r command



Continuous Data
Read iris data

> iris <- read.csv("iris150.csv", header=T)

copy r command

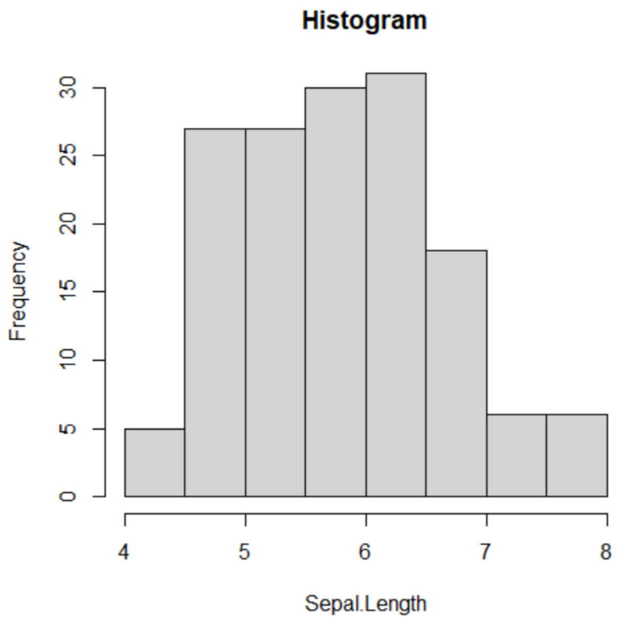
> attach(iris)

copy r command

Continuous Data Histogram, Scatter plot
Histogram

> hist(Sepal.Length, col="lightgray", ylim=c(0,30), main="Histogram")

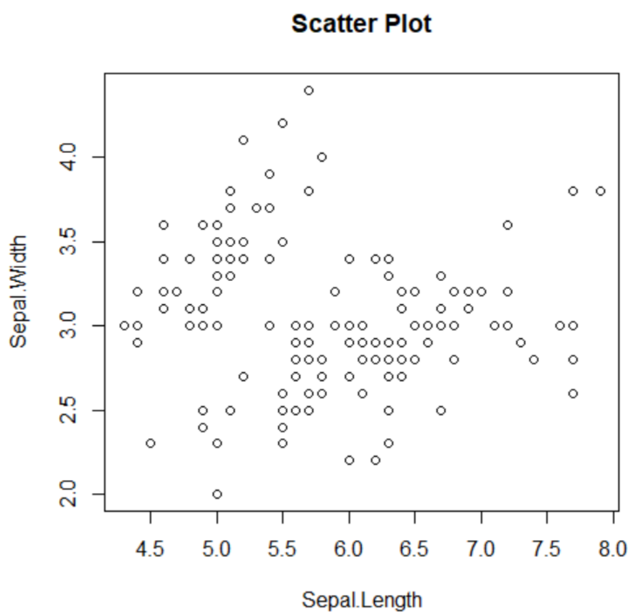
copy r command



Scatter plot

> plot(Sepal.Length, Sepal.Width, main="Scatter Plot")

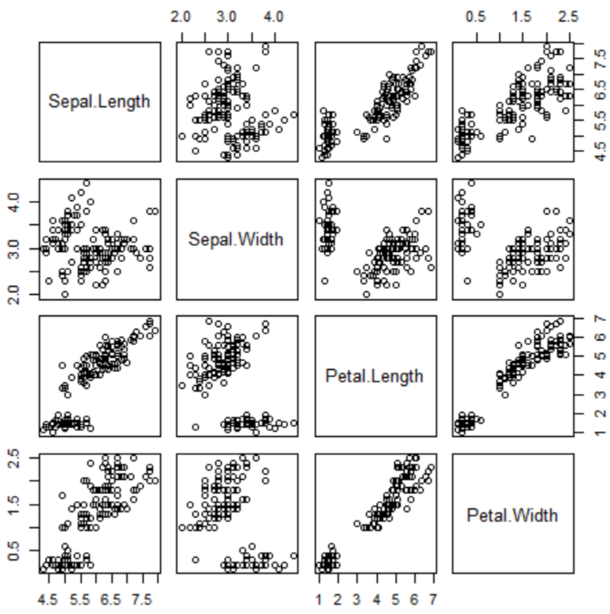
copy r command



Scatter plot matrix

> pairs(~ Sepal.Length + Sepal.Width + Petal.Length + Petal.Width, data=iris)

copy r command



Continuous Data Paralle Coordinate Plot
Divide iris data between the numerical and the categorical variable.

```
> quantData <- iris[, 2:5]
```

copy r command

```
> groupData <- iris[, 6]
```

copy r command

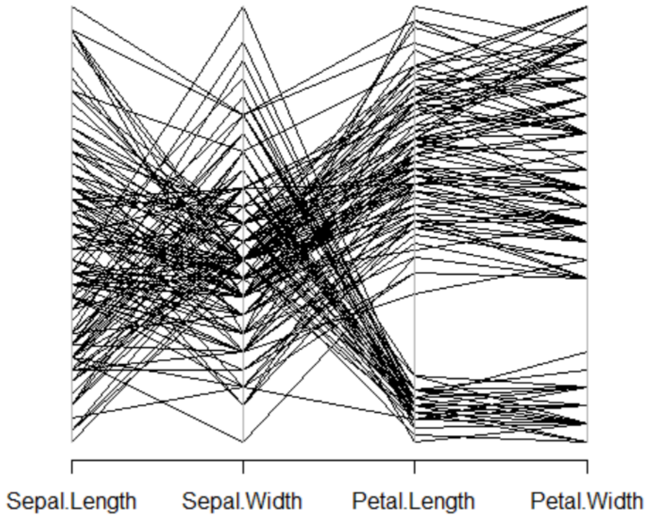
install MASS package.
In the main menu, click Packages > Load Package > select MASS package
The parcoord function from MASS package can be used to create a parallel coordinates plot in base R based on the matplot function. You can input a matrix or a data frame.

```
> library(MASS)
```

copy r command

```
> parcoord(quantData)
```

copy r command

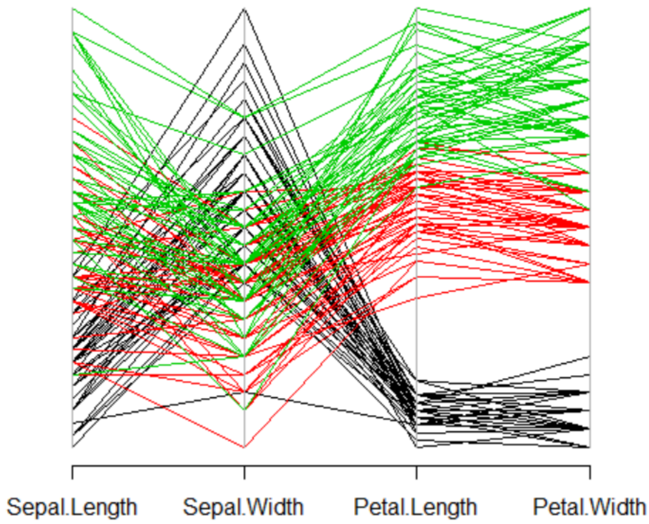



```
# Categorical variable as colors
> cols <- as.numeric(groupData)
```

copy r command

```
> parcoord(quantData, col = cols)
```

copy r command



Python Practice

Let us practice R commands using the data saved at C:\Rwork\PurchaseByCredit40.csv. The file format is a comma separated value (csv) type. You can find this file from『eStat』system. Click Ex > DataScience and then click the data 'PurchaseByCredit40.csv'. After this file is loaded to『eStat』, save it using 'csv Save' button. It will be saved at the Download folder on your PC. Copy this file to C:\Rwork\ folder.

You need to change first the working directory of R to use this data as follows.

File > Change Directory > C: > Rwork

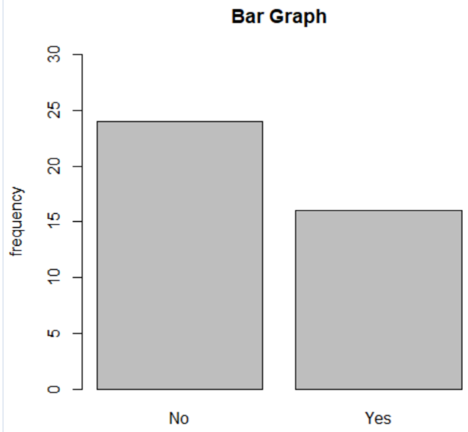
# read the data file	
> card <- read.csv("PurchaseByCredit40.csv", header=T)	copy r command
card ï..id Gender Age Income Credit Purchase 1 1 male 20s LT2000 Fair Yes 2 2 female 30s GE2000 Good No 3 3 female 20s GE2000 Fair No 4 4 female 20s GE2000 Fair Yes 5 5 female 20s LT2000 Bad No 6 6 female 30s GE2000 Fair No 7 7 female 30s GE2000 Good Yes 8 8 male 20s LT2000 Fair No 9 9 female 20s GE2000 Good No 10 10 male 30s GE2000 Fair Yes 11 11 female 30s GE2000 Good Yes 12 12 female 20s LT2000 Fair No 13 13 male 30s GE2000 Fair No 14 14 male 30s LT2000 Fair Yes 15 15 female 30s GE2000 Good Yes 16 16 female 30s GE2000 Fair No 17 17 female 20s GE2000 Bad No 18 18 male 20s GE2000 Bad No 19 19 male 30s GE2000 Good Yes 20 20 male 20s LT2000 Fair No 21 21 male 20s LT2000 Fair Yes 22 22 female 30s GE2000 Good No 23 23 female 20s GE2000 Fair No 24 24 female 20s GE2000 Fair Yes 25 25 female 20s LT2000 Bad No 26 26 female 30s GE2000 Fair No 27 27 female 30s GE2000 Good Yes 28 28 male 20s LT2000 Fair No 29 29 female 20s GE2000 Good No 30 30 male 30s GE2000 Fair Yes 31 31 female 30s GE2000 Good Yes 32 32 female 20s LT2000 Fair No 33 33 male 30s GE2000 Fair No 34 34 male 30s LT2000 Fair Yes 35 35 female 30s GE2000 Good Yes 36 36 female 30s GE2000 Fair No 37 37 female 20s GE2000 Bad No 38 38 male 20s GE2000 Bad No 39 39 male 30s GE2000 Good Yes 40 40 male 20s LT2000 Fair No	

```
> attach(card)
```

copy r command

```
# Bar graph
> plot(Purchase, main="Bar Graph", ylab="frequency", ylim=c(0,30))
```

copy r command

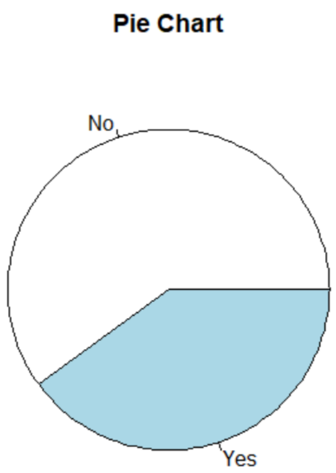



```
# Pie chart
> freq <- table(Purchase)
freq
Purchase
No Yes
24 16
```

copy r command

```
> pie(freq, main="Pie Chart")
```

copy r command




```
# Continuous Data
# Read iris data
```

```
> iris <- read.csv("iris150.csv", header=T)
```

copy r command

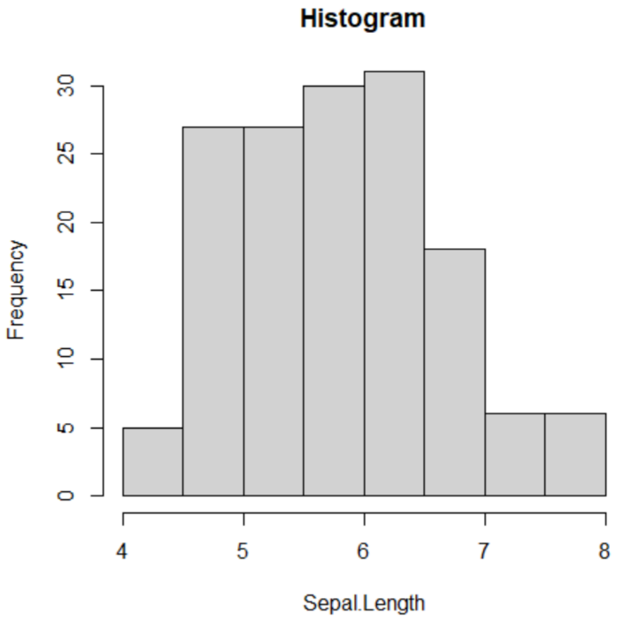
```
> attach(iris)
```

copy r command

```
# Continuous Data Histogram, Scatter plot
# Histogram
```

```
> hist(Sepal.Length, col="lightgray", ylim=c(0,30), main="Histogram")
```

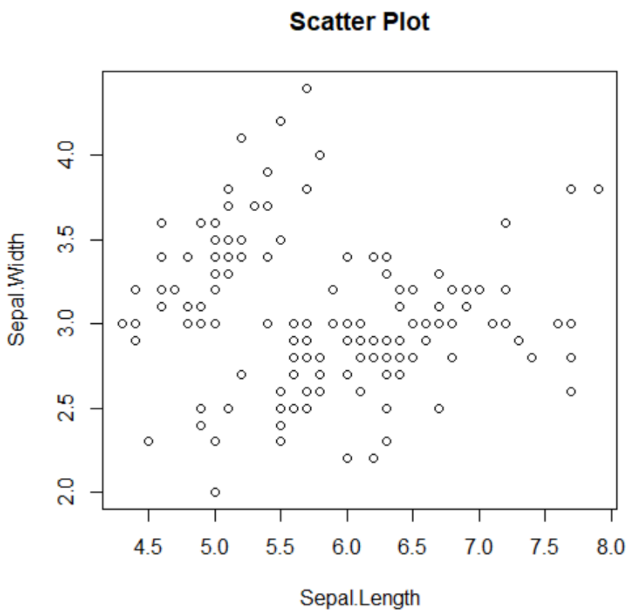
copy r command

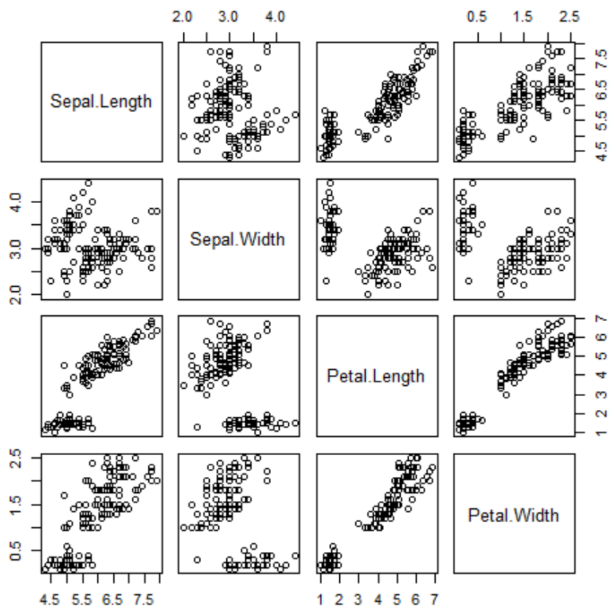


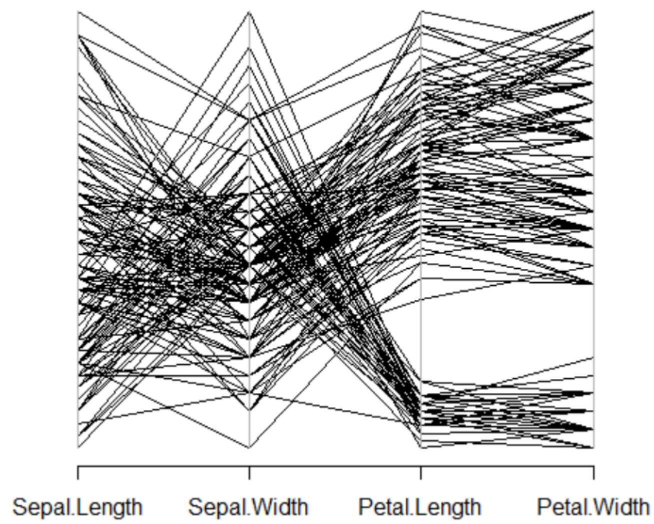

```
# Scatter plot
```

```
> plot(Sepal.Length, Sepal.Width, main="Scatter Plot")
```

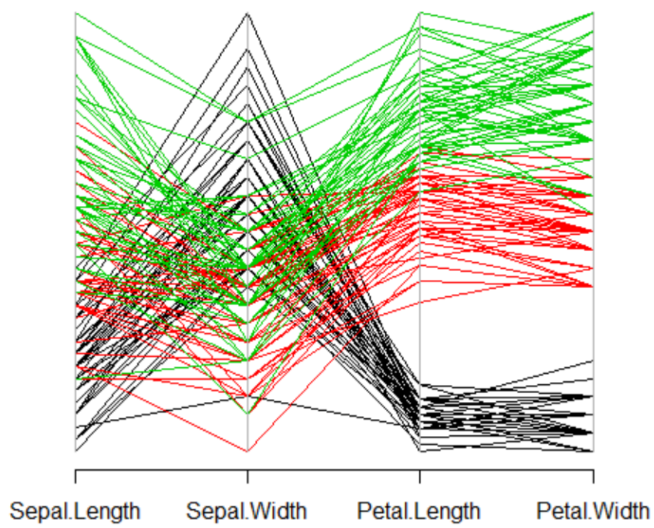
copy r command



# Scatter plot matrix	
> pairs(~ Sepal.Length + Sepal.Width + Petal.Length + Petal.Width, data=iris)	copy r command
	
# Continuous Data Paralle Coordinate Plot # Divide iris data between the numerical and the categorical variable.	
> quantData <- iris[, 2:5]	copy r command
> groupData <- iris[, 6]	copy r command
# install MASS package. # In the main menu, click Packages > Load Package > select MASS package # The parcoord function from MASS package can be used to create a parallel coordinates plot in base R based on the matplot function. You can input a matrix or a data frame.	
> library(MASS)	copy r command
> parcoord(quantData)	copy r command



# Categorical variable as colors > cols <- as.numeric(groupData)	copy r command
> parcoord(quantData, col = cols)	copy r command



2.4 Exercise

2.1 The following sample survey showed on the living standard and education level of 25 adults. In the living standard, 1 means 'high income', 2 means 'average', and 3 means 'low income', and in the education level, 1 means middle school or lower, 2 means high school, and 3 means college or higher.

id	Living standard	Education level
1	3	3

2	1	1
3	2	2
4	3	3
5	1	3
6	3	3
7	1	3
8	2	3
9	2	2
10	3	3
11	2	2
12	1	1
13	3	3
14	2	2
15	2	3
16	2	3
17	3	3
18	3	3
19	1	1
20	2	2
21	1	1
22	1	2
23	2	3
24	3	1
25	1	2

1) Classify the two variables of this data.
2) Draw a bar graph and pie chart for each of the living standard and education level.
3) Draw a bar graph on the living standard using the education level as a group variable. Draw several variations of bar graph using eStat.

2.2 The following data shows the highest temperature (degree in Celcius) in a city on a single day in August. Draw a dot graph, histogram, and stem and leaf plot.

29, 29, 34, 35, 35, 31, 32, 34, 38, 34, 33, 31, 31, 30, 34, 35,
34, 32, 32, 29, 28, 30, 29, 31, 29, 28, 30, 29, 29, 27, 28

2.3 Below are the entrance exam results for selecting new employees at a particular company. Using this data, draw and analyze histograms and boxplots by gender using eStat and R.

Male	Female
49 86 40 45 48 93 97 58 58 98 58 82 52 56 50 85 80 60 62 80 62 72 65 60 64 70 78 67 69 88	60 72 66 65 75 78 62 64 74 58 68 72 67 61 62 72 79 71 74 73

2.4 The results of observing the typing speed (X) and number of errors (Y) that 10 typists input a certain amount of documents into a computer are as follows.

Gender	X (typing speed, unit: seconds)	Y (number of errors)
M	65	6
M	60	9
F	70	2
F	73	4
M	55	9
M	65	3
M	61	7
M	59	1
F	75	4
M	64	2

1) Draw a scatter plot showing the relationship between typing speed and the number of errors. Find a regression line.
2) Draw a scatter plot showing the relationship between typing speed and the number of errors using the gender as a group variable. Find a regression line.

2.5 A particular company's annual sales and net income for the past 10 years are as follows. Draw a line graph of this data and analyze the graph.

Year	Sales (unit: million dollars)	Net profit (unit: million dollars)
2015	210	10
2016	235	11
2017	280	25

2018	350	20
2019	355	18
2020	360	20
2021	450	30
2022	560	40
2023	600	45
2024	620	40

2.6 The age and purchasing status (Y: purchase, N: non-purchase) of 10 people visiting a particular store were investigated as follows.

Age	Purchasing
23	Y
29	N
34	Y
44	Y
58	N
50	Y
46	Y
21	Y
22	N
30	N

1) Create a cross table of purchasing status by dividing the ages into under 30 and over 30.
2) Create a cross table of purchasing status by dividing the ages into under 40 and over 40.
3) Decide which of the two dividing methods above is better.

2.7 (Motor Trend Car Road Tests)
We extracted 32 observation data from the 1974 Motor Trend US magazine, which comprised fuel consumption and 10 aspects of automobile design and performance. The data have 11 variables as follows.

V1	mpg	Miles/(US) per gallon
V2	cyl	Number of cylinders
V3	disp	Displacement (cu.in.)

V4	hp	Gross horsepower
V5	drat	Rear axle ratio
V6	wt	Weight (1000 lbs)
V7	qsec	1/4 mile time
V8	vs	Engine (0 = V-shaped, 1 = straight)
V9	am	Transmission (0 = automatic, 1 = manual)
V10	gear	Number of forward gears
V11	carb	Number of carburetors

(Source: Henderson and Velleman (1981), Building multiple regression models interactively. Biometrics, 37, 391–411.)

This data are saved at the following location of 『eStat』.

[Ex] ⇨ DataScience ⇨ Mtcars.csv

1) Draw a scatter plot of the miles per gallon and the weight of a car by the number of cylinders.
2) Draw a scatter plot matrix of all continuous variable. Use Engine and Transmission as a group variable
3) Draw a parallel graph of all continuous variable. Use Engine and Transmission as a group variable