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Contents

Chapter 2

Graphical methods for presenting data

2.1 Introduction

We have looked at ways of collecting data and then collating them into tables. Frequency tables are useful methods of presenting data, they do however have their limitations. With large amounts of data graphical presentation methods are often clearer to understand. Here we look at methods for presenting graphical representations of data of the types we have seen previously.

2.2 Stem and Leaf plots

Stem and leaf plots are a quick easy and way of graphically representing data. They can be used with both discrete and continuous data. The method for creating a stem and leaf plot is similar to that for creating a grouped frequency table. The first stage, as with grouped frequency tables, is to decide on a reasonable number of intervals which span the range of data. The interval widths for a stem and leaf plot must be equal. Because of the way the plot works it is best to make the width either an integer power of 10 (e.g. $1 = 10^0$ or $10 = 10^1$ or $100 = 10^2$ or $1000 = 10^3$ or ...or $0.1 = 10^{-1}$ or $0.01 = 10^{-2}$ or $0.001 = 10^{-3}$ or ...) or 2 or 5 times a power of 10 (e.g. $20 = 2 \times 10^1$ or $0.05 = 5 \times 10^{-2}$). We can use 2 or 5 because these are factors of 10. We are not free as a result of this condition to choose the boundaries of the intervals. Once we have decided on our class intervals we can construct the stem and leaf plot. This is perhaps best described by demonstration.

Consider the following data, $11, 12, 9, 15, 21, 25, 19, 8$. The first step is to decide on a interval widths which can be the same as the *stem unit*. One obvious choice would be 10s. This would make the *leaf unit* 1. The stem and leaf plot is constructed as below.

0	8 9
1	1 2 5 9
2	1 5

Stem **Leaf**

$$n = 8, \quad \text{stem unit} = 10, \quad \text{leaf unit} = 1.$$

You can clearly see where the data have been put. The stem units are to the left of the vertical line, while the leaves are to the right. So, for example, our first observation, 11, is made up of a stem unit of one 10 and a leaf unit one 1.

As an example where the interval width is not a power of 10, consider the following observations

$$17, 18, 15, 14, 12, 19, 20, 21, 24, 15.$$

If you were to choose 10 as the stem unit and 1 as the leaf unit, the stem and leaf plot would look like

$n = 10$

1	2	4	5	5	7	8	9
2	0	1	4				

Stem unit $= 10$, Leaf unit $= 1$.

Here the interval width is 20.

There is not much of a visible pattern in the data in this plot. If we choose $5 \times 10^0 = 5$ units as our interval width, the stem unit remaining as 10's, again with 1 as our leaf unit, the stem and leaf plot would look as follows.

$n = 10$

1	2	4			
1	5	5	7	8	9
2	0	1	4		

Stem unit $= 10$, Leaf unit $= 1$.

Changing the interval width like this produces a plot which starts to show some sort of pattern in the data. Graphical presentations are intended to draw out such patterns.

Let us work through the following example. The observations in the table below are the recorded time in seconds it takes to get through to an operator at a telephone call centre.

54	56	50	67	55	38	49	45	39	50
45	51	47	53	29	42	44	61	51	50
30	39	65	54	44	54	72	65	58	62

$n =$

Stem **Leaf**

Stem unit $=$ Leaf unit $=$

If there is more than one significant figure in the data, the extra digits are cut not rounded to the nearest value, that is to say 2.97 would become 2.9. To illustrate this, consider the following data on lengths (in cm) of items on a production line:

$$2.97, 3.81, 2.54, 2.01, 3.49, 3.09, 1.99, 2.64, 2.31, 2.22.$$

The stem and leaf plot for this is as follows.

$n = 10$

1	9		
2	0	2	3
2	5	6	9
3	0	4	
3	8		

Stem unit $= 1$ cm, Leaf unit $= 0.1$ cm.

Here the interval width is $5 \times 10^{-1} = 0.5$. This allows for greater clarity in the plot.

2.2.1 Using Minitab

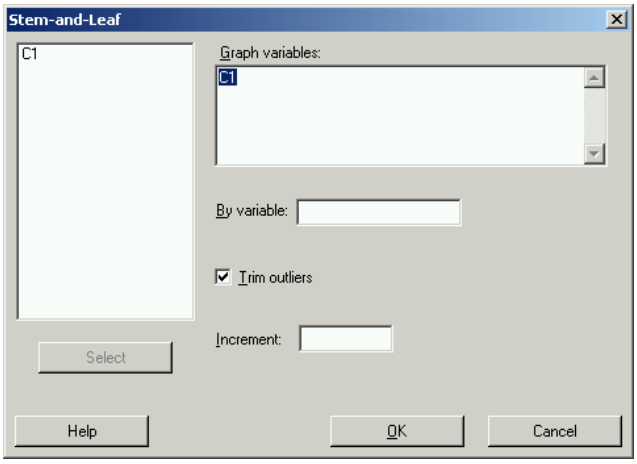
With the small data sets we have seen so far, it is obviously relatively easy to create the stem and leaf plots by hand. With larger data sets this would be more problematic and certainly time consuming. Fortunately there are computer packages that will create these plots for us. **MINITAB** is one such package and we will be using this as an example of what it is possible to achieve using computers. **MINITAB** is an application found on university PC clusters and is run by clicking on

```
Start > All Programs > Statistical Software > Minitab 14 > Minitab 14
```

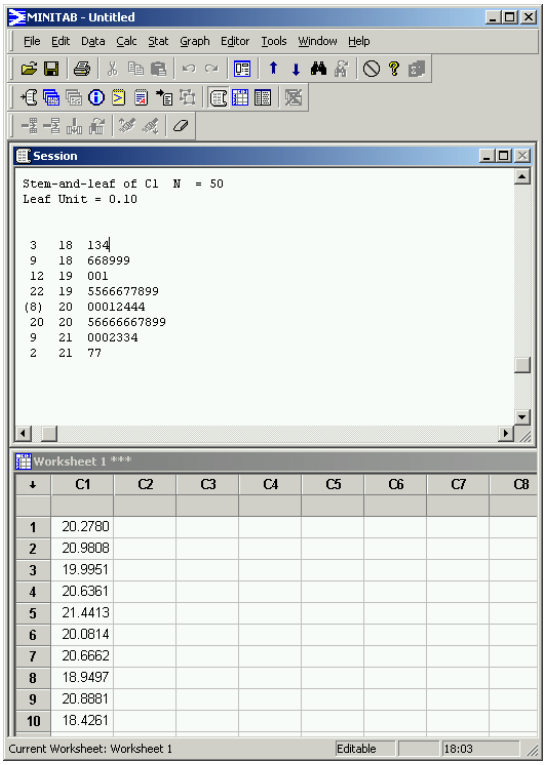
You will see two windows: a session window and a worksheet. Data are entered into columns labelled C1, C2, C3 etc in the worksheet. Suppose C1 contains some data. To obtain a stem and leaf plot of these data you would need to do the following:

`Graph > Stem-and-Leaf...`

This brings up the window below. You need to type in C1 under `Variable` and click `OK`. If you want you can choose the stem unit by entering a value in `Increment` first, otherwise the programme selects this for you.



This creates a stem and leaf plot in the session window:



It is easy to see some of the advantages of a graphical presentation of data. For example, here you can clearly see that the data are centered around a value in the low 200's and fall away on either side. From stem and leaf plots we can quickly and easily tell if the data are symmetric or asymmetric. We can see whether there are any *outliers*, that is, observations which are either much larger or much smaller than is typical of the data. We could perhaps even tell whether the data are *multi-modal*. That is to say, whether there are two or more peaks on the graph with a gap between them. If so this might suggest that the sample might contain data from two or more groups.

2.3 Bar Charts

Bar Charts are common and clear ways of presenting categorical data or any ungrouped discrete frequency observations. As with stem and leaf plots, various computer packages allow you to produce these with relative ease. First let us work through the process of producing these by hand. This will enable you to get a clear idea of how these charts are constructed.

Constructing a bar chart is a 5 step process:

1. First decide what goes on each axis of the chart. By convention the variable being measured goes on the horizontal (x-axis) and the frequency goes on the vertical (y-axis).
2. Next decide on a numeric scale for the frequency axis. This axis represents the frequency in each category by its height. It must start at zero and include the largest frequency. It is common to extend the axis slightly above the largest value so you are not drawing to the edge of the graph.
3. Having decided on a range for the frequency axis we need to decide on a suitable number scale to label this axis. This should have sensible values, for example, $0, 1, 2, \ldots,$ or $0, 10, 20 \ldots$, or other such values as make sense given the data.
4. Draw the axes and label them appropriately.
5. Draw a bar for each category. When drawing the bars it is essential to ensure the following:
   - the width of each bar is the same;
   - the bars are separated from each other by equally sized gaps.

Recall the example on students' modes of transport:

Student	Mode	Student	Mode	Student	Mode
1	Car	11	Walk	21	Walk
2	Walk	12	Walk	22	Metro
3	Car	13	Metro	23	Car
4	Walk	14	Bus	24	Car
5	Bus	15	Train	25	Car
6	Metro	16	Bike	26	Bus
7	Car	17	Bus	27	Car
8	Bike	18	Bike	28	Walk
9	Walk	19	Bike	29	Car
10	Car	20	Metro	30	Car

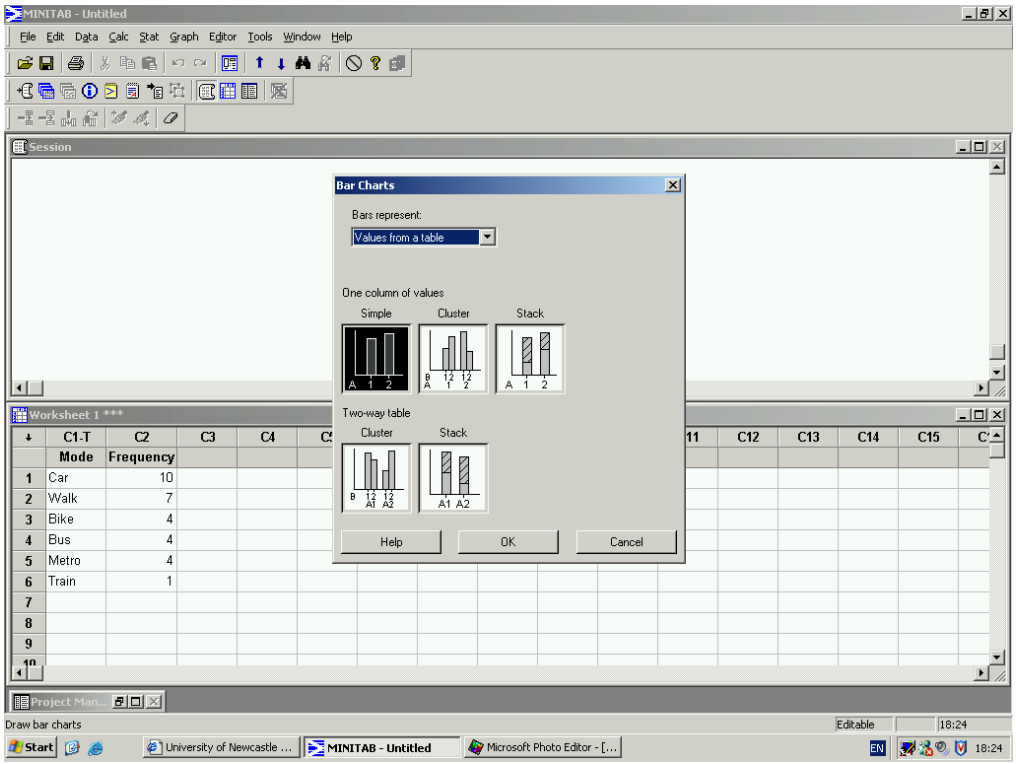
The first logical step is again to put these into a frequency table, giving

Mode	Frequency
Car	10
Walk	7
Bike	4
Bus	4
Metro	4
Train	1
Total	30

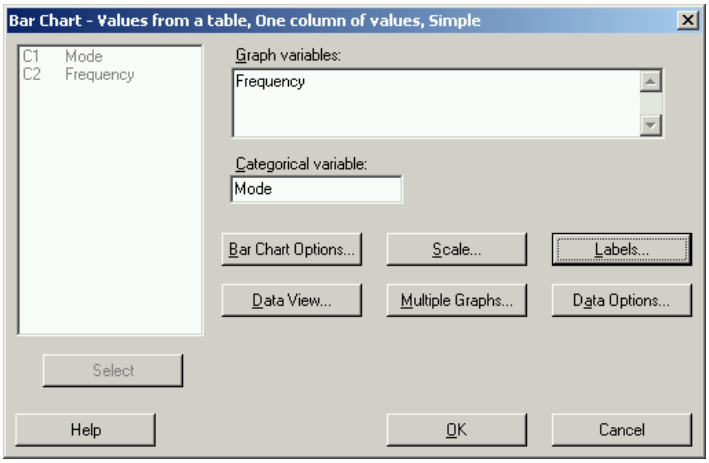
We can then present this information as a bar chart:

Such graphs are easily drawn using **MINITAB**:

1. First enter the data in the worksheet, either in summary format or as raw data, with column C1 containing the categories and the (raw or frequency) counts in column C2.
2. `Graph > Bar Chart...`



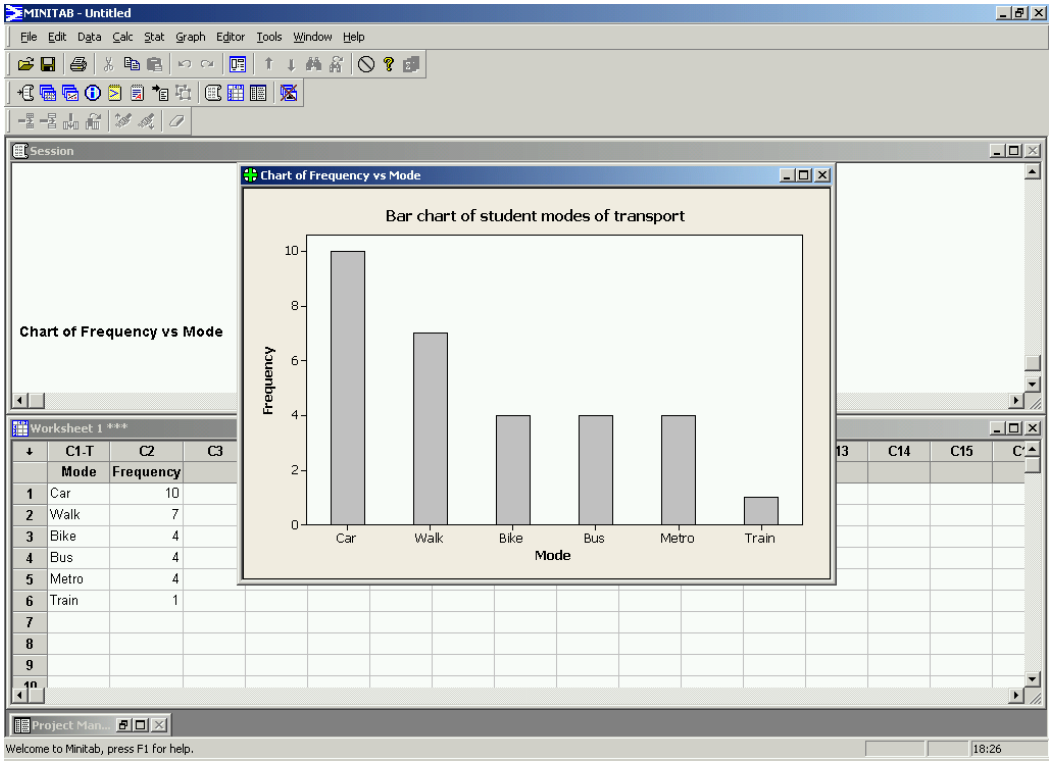
3. Select the appropriate data format (raw data or tabulated data), the columns containing the data, and the graph format



Note: options exist to configure the graph e.g. `Label` can be used to give the graph a title.

4. When ready click on **OK**

This procedure produces the chart



This bar chart clearly shows that the most popular mode of transport is the car and that the metro, walking and cycling are all equally popular (in our small sample). Bar charts provide a simple method of quickly spotting simple patterns of popularity within a discrete data set.

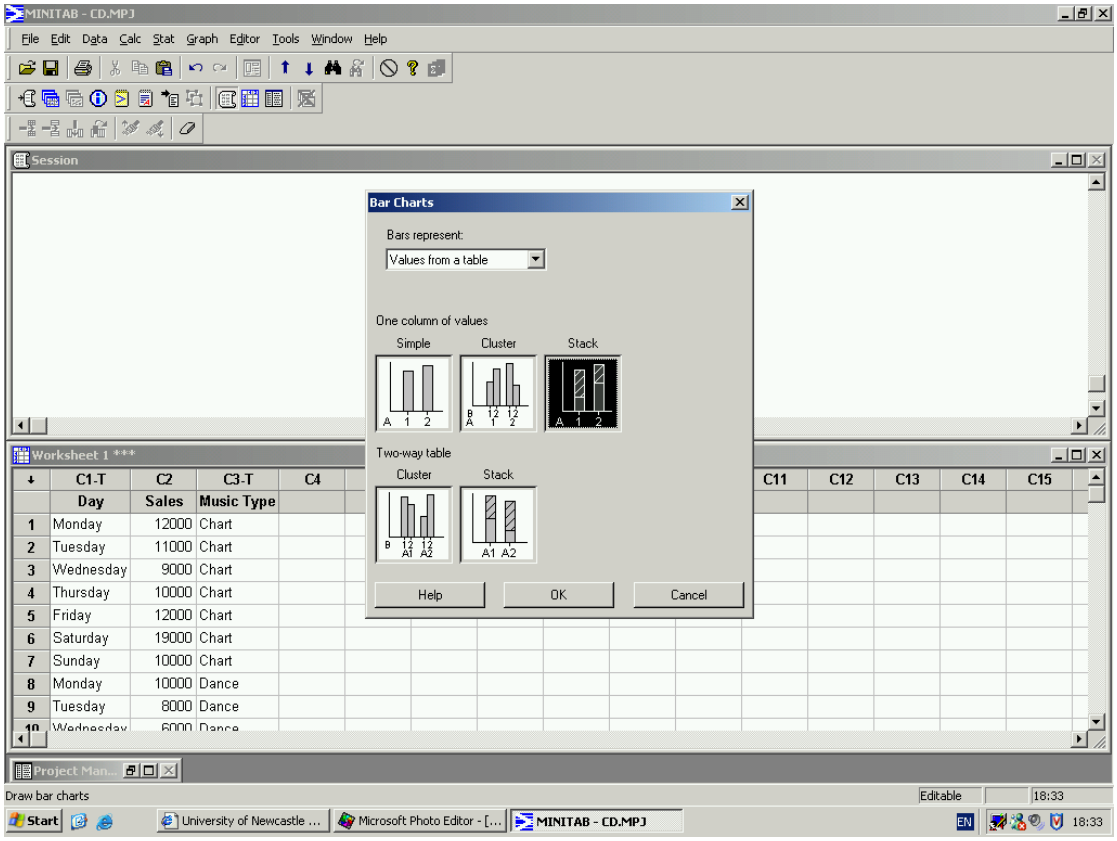
2.4 Multiple Bar Charts

The data below gives the daily sales of CDs (in £) by music type for an independent retailer.

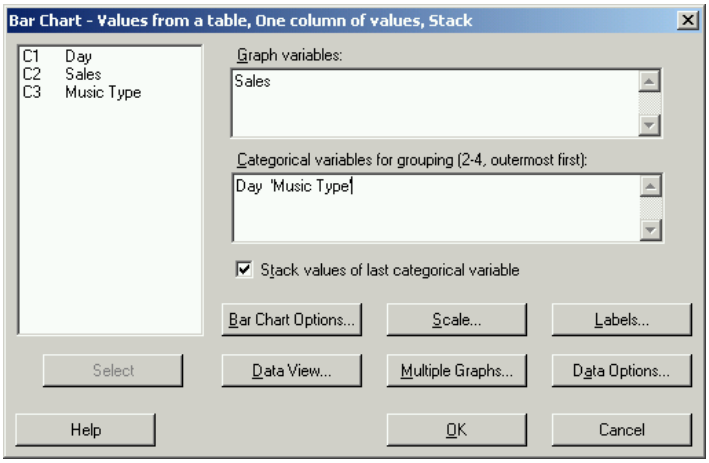
Day	Chart	Dance	Rest	Total
Monday	12000	10000	2700	24700
Tuesday	11000	8000	3000	22000
Wednesday	9000	6000	2000	17000
Thursday	10000	5000	2500	17500
Friday	12000	11000	3000	26000
Saturday	19000	12000	4000	35000
Sunday	10000	8000	2000	20000
Total	83000	60000	19200	162200

Bar charts could be drawn of total sales per music type in the week, or of total daily sales. It might be interesting to see daily sales broken down into music types. This can be done in a similar manner to the bar charts produced previously. The only difference is that the height of the bars is dictated by the total daily sales, and each bar has segments representing each music type. This is done in **MINITAB** as follows:

1. Enter the data into the worksheet, the types of music in columns and the days as rows.
2. `Graph > Bar Chart...`
3. Select the appropriate data format and the `Stack` graph format.

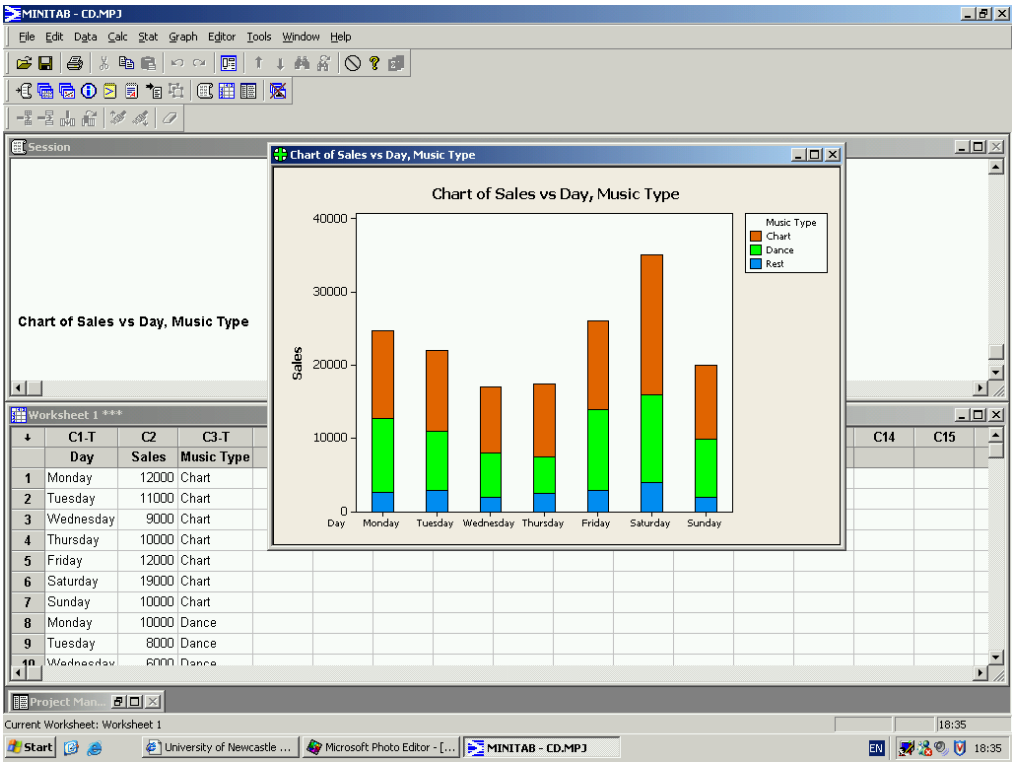


4. Click `OK`
5. Enter the column containing the `Sales` data under `Graph variables` and the `Day` and `Music Type` in the grouping dialogue box



6. Click `OK`.

The MINITAB worksheet and chart this procedure produces are



These types of charts are particular good for presenting such financial information or illustrating any breakdown of data over time, for example, the number of new cars sold by month and model.

2.5 Histograms

Bar charts have their limitations. They can not be used to present data on continuous variables. When dealing with continuous variables a different kind of graph is required. This is called a *histogram*. At first sight these look similar to bar charts. There are however two critical differences:

- the horizontal (x-axis) is a continuous scale. As a result of this there are no gaps between the bars (unless there are no observations within a class interval);
- the height of the rectangle is only proportional to the frequency if the class intervals are all equal. With histograms it is the area of the rectangle that is proportional to their frequency.

Initially we will only consider histograms with equal class intervals. Those with uneven class intervals require more careful thought.

Producing a histogram, is much like producing a bar chart and in many respects can be considered to be the next stage after producing a grouped frequency table. In reality it is often best to produce a frequency table first which collects all the data together in an ordered format. Once we have the frequency table, the process is very similar to drawing a bar chart.

1. Find the maximum frequency and draw the vertical (y-axis) from zero to this value, including a sensible numeric scale.

2. The range of the horizontal (x-axis) needs to include not only the full range of observations but also the full range of the class intervals from the frequency table.

3. Draw a bar for each group in your frequency table. These should be the same width and touch each other (unless there are no data in one particular class).

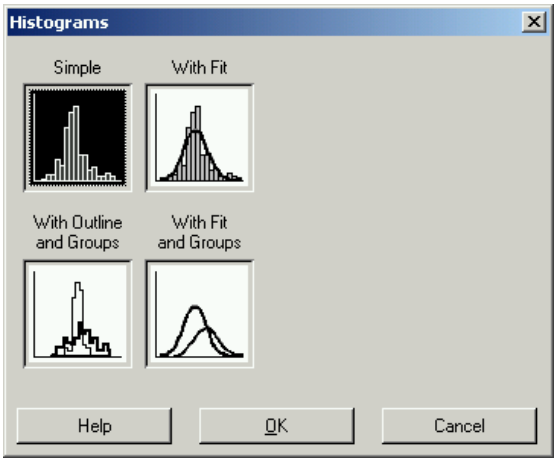
The frequency table for the data on service times for a telephone call centre was

Service time	**Frequency**
$175 \leq time < 180$	1
$180 \leq time < 185$	3
$185 \leq time < 190$	3
$190 \leq time < 195$	6
$195 \leq time < 200$	10
$200 \leq time < 205$	12
$205 \leq time < 210$	8
$210 \leq time < 215$	3
$215 \leq time < 220$	3
$220 \leq time < 225$	1
Total	50

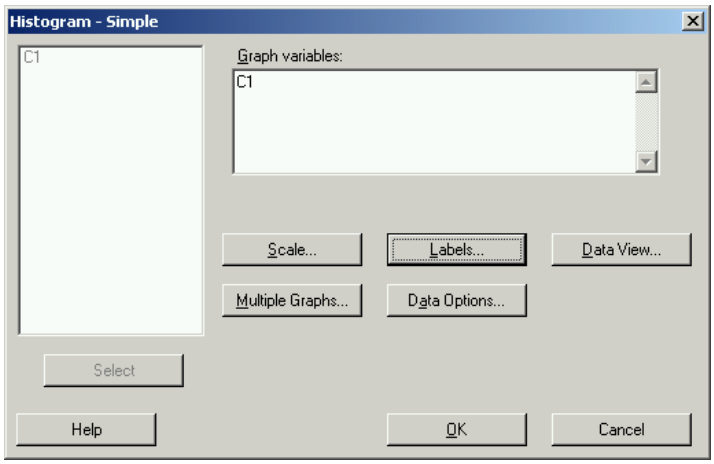
The histogram for these data is

Normally, as with stem and leaf plots and bar charts we would get **MINITAB** to do this for us.

1. Enter the data in column C1 of the worksheet. For illustrative purposes I have randomly generated 500 observations in this column.
2. `Graph > Histogram...`
3. Select the `Simple` graph format



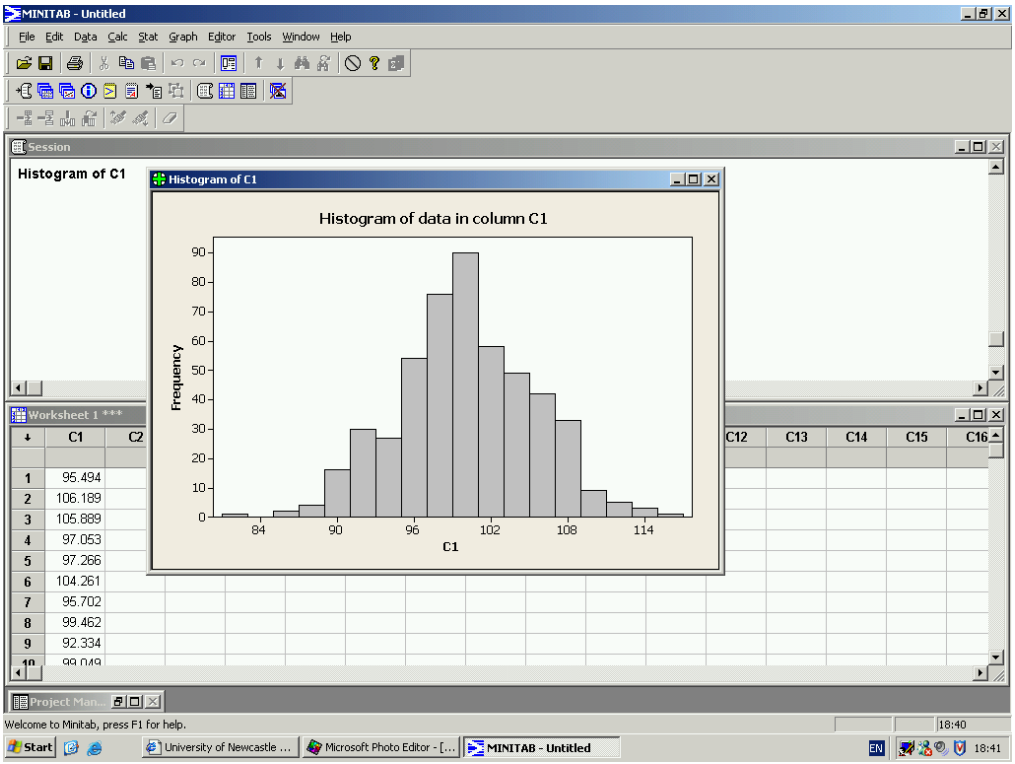
4. Select C1 under `Graph variables`.



   Note: various advanced options are available e.g. a title can be added by clicking `Labels`

5. When happy with your choices click `OK`.

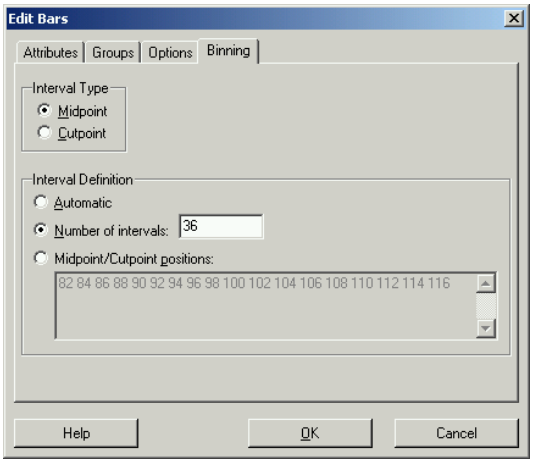
These instructions produce the following histogram:



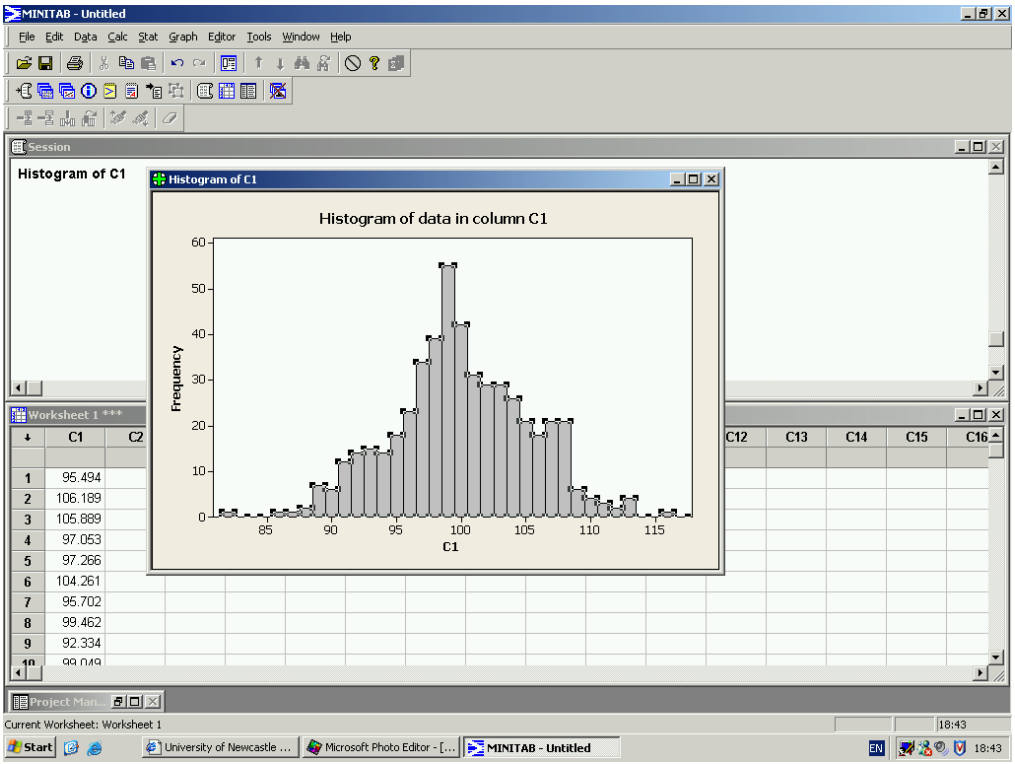
The histogram produced can be amended by `right-clicking` on the graph. For example, the intervals used in the histogram can be changed or, more simply, the number of intervals using

`Edit bars > Binning`

We can double the number of intervals (from 18 to 36 intervals) using the `Binning` dialogue box

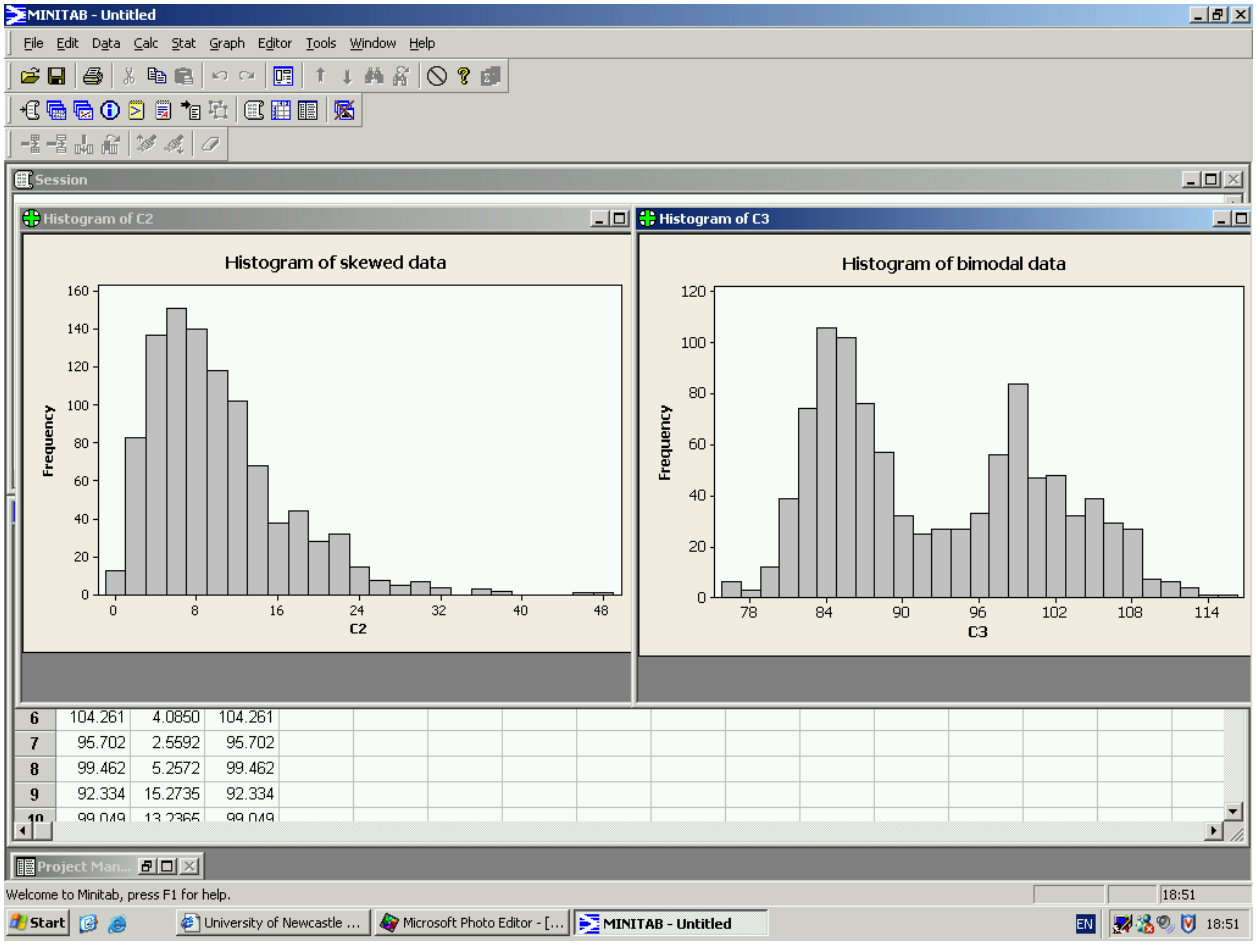


This changes the histogram to



Histograms are useful tools in data analysis. They are easy to produce in **MINITAB** for large data sets and provide a clear visual representation of the data. Using histograms, it is easy to spot the *modal* or most popular class in the data, the one with the highest peak. It is also easy to spot simple patterns in the data. Is the frequency distribution symmetric, as the histograms produced above, or is it skewed to one side like the left-hand histogram in the following graphic.

Histograms also allow us to make early judgements as to whether all our data come from the same population. Consider the right-hand histogram in the graphic below. It clearly contains two separate modes (peaks), each of which has its own symmetric pattern of data. This clearly suggests that the data come from two separate populations, one centred around 85 with a narrow spread and one centred around 100 with a wider spread. In real situations it is unlikely that the difference would be as dramatic, unless you had a poor sampling method. However the drawing of histograms is often the first stage of more complex analysis.



Finally, be careful when drawing histograms of observations on variables which have boundaries on their ranges. For example heights, weights, times to complete tasks etc. can not take negative values so there is a lower limit at zero. Computer programs do not automatically know this. You should make sure that the lower limit of the first class interval is not negative in such cases.

2.6 Exercises 2

1. The following table shows the weight in kilograms of 50 sacks of potatoes leaving a farm shop.

10.41	10.06	9.38	11.36	9.65
11.24	10.58	8.55	10.47	8.22
9.36	9.63	10.33	10.05	11.57
11.36	10.82	8.93	10.08	9.53
10.05	11.30	11.01	9.72	10.67
9.91	10.26	10.67	10.21	8.18
8.70	9.49	10.98	10.01	9.92
9.27	11.69	9.66	9.52	10.40
10.61	8.83	10.11	10.37	9.73
10.72	10.63	12.86	10.62	10.26

   Display these data in a stem and leaf plot. Note the number of decimal places and adjust accordingly. State clearly both the stem and leaf units.

2. A market researcher asked 650 students what their favourite daily newspaper was. The results are summarised in the frequency table below. Represent these data in an appropriate graphical manner.

The Times	140
The Sun	200
The Sport	50
The Guardian	120
The Financial Times	20
The Mirror	80
The Daily Mail	10
The Independent	30

3. Produce a histogram for the data on length of mobile phone calls in Exercises 1 (listed again below) and comment on it.

281.4837	293.4027	306.5106	286.6464	298.4445
312.7291	327.7353	311.5926	314.8501	303.3484
270.7399	293.9364	310.9137	346.4497	304.6044
304.1124	320.7182	283.6594	337.5806	259.6408
305.4378	317.9180	289.5667	286.9626	300.5140
278.3108	300.1725	292.6725	312.9645	302.5770
293.2735	267.5344	326.9056	257.7226	285.9805
299.6535	293.9145	303.9191	323.7993	263.5242
281.1613	306.9344	310.2583	301.6963	313.9611
314.8500	292.0031	302.4314	267.9781	292.0917