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Chapter 1

Introduction

1.1 Overview

The *Quick and Dandy Plotter (QDP)* program reads ASCII files containing various plotting commands and data. *QDP* then calls the *PLT* subroutine which then executes the commands and plots the data. At this point the "`PLT>`" prompt appears and the user can then proceed to enter additional PLT commands which can:

- Display information on about the interactive commands *via* `HElp`,
- Override various PLT defaults,
- Override the PLT commands found in the QDP file,
- Add/remove labels,
- Plot data with various combinations of lines, markers, and error bars,
- Change the appearance/style of the of the plot, for example converting all text into the Roman Font,
- Plot the data as a function of a different x variable,
- Change the number of panels in which the data is plotted,
- Define models and to calculate the 'best fit' parameter values,
- Generate a hardcopy.

Thus the interactive PLT commands allow you to both tailor the plot to your needs/taste and to do some simple analyses of the data. PLT commands can be placed in the QDP file, in an indirect command and/or in a command array created by the calling program. For example, if you have a set of commands that you commonly use, then you can place those commands in a file, and then have PLT execute the commands that it finds in that file. Since exactly the same command syntax is used in all places, it is not necessary to learn a special programming language to write software that uses PLT. Programmers can try out PLT commands interactively to find a set that works best with the type of data being plotted, and then make these commands the default values.

The PLT software is highly portable. PLT uses the PGPLOT Graphics Subroutine Library written by T. J. Pearson at the California Institute of Technology. PGPLOT has been ported to many systems ranging from MS-DOS machines to UNICOS Crays. PLT is actively supported on VAX VMS, SUN UNIX, and NeXT systems. The code is in standard Fortran and so can easily ported to other systems and is running on MS-DOS, PRIME, and IBM RS/6000 systems.

This manual provides an overview of how to use PLT. Not all commands will be described in the overview, however, Appendix B includes the contents of the on-line help which does contain every command.

The rest of this introduction defines a few terms and the discusses the syntax conventions used. If you wish to quickly get started with using PLT, you should skip to the next chapter. Once you have mastered the basics, you should come back and read the following sections.

1.2 Definitions

PLT operates on quantities called *vectors* which can consist of one, two, or three columns in this rectangular array. If the data contains no errors, then each column is a vector. If the data contains symmetric errors, then it takes two columns to denote a single vector. Likewise if you have two sided errors (*e.g.*, $+5,-2$), it will take 3 columns to denote a vector. If one number in a vector has an error, then all numbers in that vector must have the same type of error. The vectors are independent of each other, and so some vectors can have errors and others can be without.

The PLT default is to make each vector an independent plot group. The PLT `SKip` command can be used if you have just two vectors and you wish to create several plot groups within those vectors.

Viewport denotes the physical area of the plotting surface that you are using. PLT (*via* PGPLOT) uses device-independent coordinates to denote the viewport, with (0.0,0.0) denoting the bottom left corner of the display surface, and (1.0,1.0) the top right corner.

PLT can be used to fit a model to the data. A *model* consists of one or more components which are added together. Each component must have one or more parameters; when fitting the data, the parameters are varied to minimize χ^2. There is no way to multiply the built-in components together.

A *COD file* is an ASCII text file that contains a function written in the COD programming language. PLT allows you to define a model in which one of the components is a function contained a COD file. When FIT evaluates that component, the COD function is called and should return with the function evaluated for the current parameter set.

1.3 Syntax

PLT does not distinguish between upper and lower case. When matching the characters you type with possible commands, PLT only matches characters in the *shortest unique abbreviation* which, in this documentation, is denoted by upper case. Thus both `color` and `colour` will match the `COlor` command. Of course, some caution is required as

`cosmopolitan` will also match `COlor`. As new commands are added, a previously acceptable abbreviation could refer to one of the new commands. To avoid such potential conflicts, you are encouraged to use three letter abbreviations.

In this documentation, a name in all lower case name is a mnemonic and should not be entered. For example, in `Rescale X xmin,xmax` both "`xmin`" and "`xmax`" should be replaced with numbers.

In PLT, arguments can be separated by a comma and/or any number of spaces and tab characters. Thus, the strings `1 2 3` , `1,2,3` , `1, 2, 3` , and `1 , 2 , 3` are all parsed as three arguments. Sometimes it is necessary to leave a placeholder that indicates an argument should be skipped. This is done by entering two adjacent commas. The string `1,,3` is parsed as three arguments with the second argument being null. Null arguments are often used to indicate that the current value should not be changed. If it is necessary to enter any special character as part of an argument, the argument should be enclosed in quote marks. The string `1,"2,3,4",5` would be parsed as three arguments and the second argument would be the string `2,3,4` .

PLT allows you to embed the simple mathematical operators, `+` , `-` , `*` , and `/` into numbers. Thus, the argument `2*3` would be parsed as 6. The numeric expression is evaluated from left to right; hence, the argument `1+2/4` is parsed 3/4 or 0.75. This syntax can be useful in QDP files. For example, suppose column 1 is the time in seconds, and you wish to plot time in hours. This can be done with a global edit that appends the string `/3600.` to the numbers in column 1.

The character `#` is used to denote a number. When you see this character, you should not type `#` , but rather replace it with a number. Likewise, the character `$` denotes a string. Optional arguments are enclosed in square brackets `[...]` . If an argument must be one of several discrete choices, the choices will be listed separated by vertical lines `|` .

Chapter 2

Basics

2.1 QDP Files

The quickest and most convenient way to use PLT is with a QDP file. A QDP file is an ASCII text file that contains a rectangular array of data. Since QDP files are ASCII they are easy to create and highly portable to different computer systems. All QDP files must contain a two dimensional array of data. The row-column location of a number in the file determines the row-column index in the data array passed to PLT. It is possible, but not necessary, to include QDP and/or PLT commands at the top of the QDP file. These commands often serve to document the data. All the QDP program does is to read the file, and to pass the information to the PLT subroutine.

In order to try out the examples in this chapter and the next, you should first create a "`DEMO.QDP`" file that contains the following:

```
1   1  16
2   4   9
3   9   4
4  15   1          ! Yes 15 and NOT 16
```

(`XANADU:[PLOT.QDP]DEMO.QDP` contains a pre-typed version of this file.) This example file contains no QDP or PLT commands. The QDP default is to assume that each column of numbers is a separate vector.

This example illustrates that QDP files can contain comments. Comments begin with the comment character `!` and continue to the end of the line. The above example contains the comment "`Yes 15 and NOT 16`". Comments are completely ignored. This documentation will often include a comment with the example commands. When trying out the command, you do not need to type the comment; however, if you do type it, then no harm will be done.

The QDP data lines are free format and the numbers can be separated by spaces, a comma, or tabs. Every row should contain the same number of columns; however, if some data are missing, you can enter the word `NO` instead of an actual number. QDP translates the `NO` into the PLT no-data flag; which will be ignored by PLT.

2.2 Plot the File

Once you have created a version of `DEMO.QDP`, you can run QDP with

```
$ QDP DEMO
```

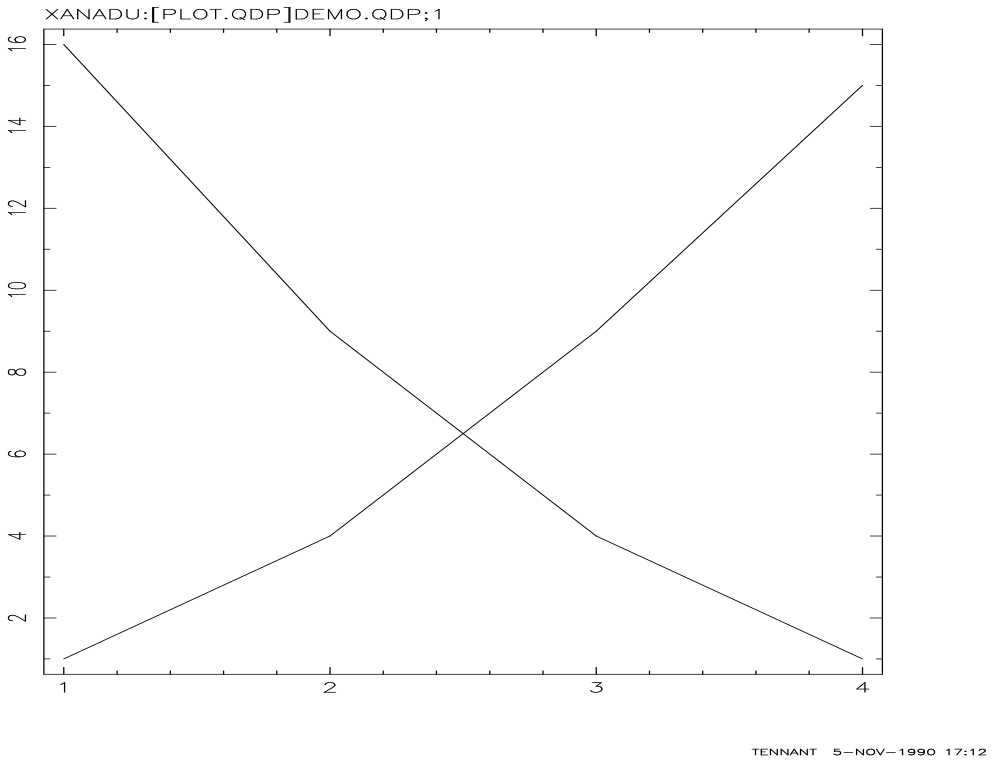

Figure 2.1: The default appearance of the `DEMO.QDP` file.

(If QDP fails to run, then you might need to define the QDP symbol as described in Appendix D, **Installation Guide**.) It is not necessary to enter the `.QDP` extension as the QDP program assumes that as the default. When the program starts, you will receive the following message:

```
To produce plot, please enter
PGPLOT file/type:
```

You should enter the PGPLOT specification for the device on which you wish to plot. If you do not know the device name, then enter `?` and all the device types supported by your local version of PGPLOT will be listed. If your terminal supports Tektronix graphics, then enter `/TE` to make the plot appear on your terminal. You might also try `/RE` for Retrographics. Most Tektronix emulators support the Retrographics extensions that allow the software to toggle between text and graphics modes.

A graph containing two lines will now be drawn as illustrated in figure 2.1. Since the file contained three columns of numbers, the default mode assumes there are three plot groups. The first plot group determines the x coordinate. The next two columns are plotted as two lines. On a color display the first line will be red and the second green, which are the default colors for plot groups 2 and 3. The name of the QDP file appears in the top left of the plot and your userid, current date, and time appear in the bottom right of the plot. The `PLT>` prompt will now appear. In the following sections you will see how to enter various commands to change the default plot. The most useful command for beginners is the `HElp` command, which can be used to get

instructions on how to use any command.

Another useful command is `EXit` that will get you out of the PLT subroutine. If you are in QDP, control will be returned to the operating system; in other programs, control will be returned to the calling program.

2.3 Rescaling

PLT chooses a default scale that makes all the data visible. The examples in this section will illustrate the `Rescale` command that can be used to change this scale. Using the plot created in the previous section, enter

```
PLT> R X 0 5
```

When you enter this command, the graph is redrawn with 0.0 on the left side and 5.0 on the right side of the viewport. Likewise `R Y 0 20` will put 0.0 on the bottom and 20.0 on the top. If you wish to change one number without the other, you can skip the field with commas or terminate the line before changing the default. For example, both

```
PLT> R Y 0 20     ! Set both lower and upper limit
```

and

```
PLT> R Y,,20      ! Set upper limit to 20, leaving lower unaffected
PLT> R Y 0        ! Set lower limit to 0, leaving upper unaffected
```

will produce the same effect. If you wish to change both the `X` and `Y` limits, then use

```
PLT> R 1 5 1 16  ! Set X-range to 1 to 5, and Y-range 1 to 16
```

If you wish to go back to the default scale, then use `R` with no arguments:

```
PLT> R Y          ! Will reset Y limits to default
PLT> R            ! Will reset both X and Y limits to default
```

At any time you can find out what the current scale limits are with

```
PLT> R ?
 Current Gap=   .025
Window   XLAB      XMIN         XMAX         YLAB      YMIN         YMAX
   1 :             .9250    ,  4.075     :             .6250    ,  16.38
PLT>
```

This produces a table of the current scaling parameters. The current gap is the default size of the gap between the edge of the data and the edge of the plot. For the default scale, the difference between the minimum/maximum and the data minimum/data maximum is due to the gap. With a gap of zero, the default minimum/maximum value will exactly match the data minimum/data maximum. The default is to plot all plot groups into just one window hence only one row appears in the table corresponding to that window. The columns labeled `XLAB` and `YLAB` contain the current x and y labels, which are currently blank.

If you want to see what the data minimum and maximum values are you should use

```
PLT> SHow Group

Grp  Wind    Label     XData Min    XData Max    YData Min    YData Max
  1    -1             :  1.000    ,   4.000     :  1.000    ,   4.000
  2     1             :  1.000    ,   4.000     :  1.000    ,   15.00
  3     1             :  1.000    ,   4.000     :  1.000    ,   16.00
```

The three rows correspond to the three plot groups. The column labeled `Wind` contains the window in which the group is currently being plotted, and a negative number indicates that the group is not actually plotted. In this example, group 1 is used to determine the x coordinate and so is not actually plotted. The columns labeled `YData Min` and `YData Max` contain the actual data minimum and maximum of that plot group.

2.4 Making a Hardcopy

PLT makes a hardcopy by using the same PGPLOT routines but routed to a different graphics device. Thus the command does not make a hardcopy of what is currently on your screen, but rather, what would be plotted if you reissued the `Plot` command. The `HArd ?` command will display the name of your current default hardcopy device. It is possible to override this default when you enter the `HArd` command, thus `HArd /VPS` would make a vertical (portrait) mode Postscript file no matter what the default is. If you would like a different default than what is set up on your system, then you should define the logical name or on UNIX, the environment variable, `PLT_HARDCOPY` to contain the default you want. Let's assume the default is OK. So, merely enter

```
PLT> CSize 1.3    ! To increase the character size a bit
PLT> FOnt Roman   ! To use the nice looking Roman font
PLT> HArdcopy     ! To make a hardcopy file
```

PGPLOT would have now made a file in your current directory. You should consult your PGPLOT manual for the rules on how to print this file. On many systems it is possible to use the `@HARD` command that will both create a file and then spool the file to the printer.

The default PLT font is the Simple font because it plots the fastest. When you are making a hardcopy, speed is less important than quality. Therefore, you are encouraged to use the Roman font, which will give a more professional look to your hardcopy. As most journals greatly reduce the size of figures before printing, you should increase the character size. In the above example, `CSize 1.3` makes the character size a factor of 1.3 times larger than the default. The default line width is one, which is the thinest possible line. On some laser printers, this is too thin, and therefore, you should increase the line width, using the `LWidth` command. Using `LWidth 7` is not unreasonable for publication quality on some printers. In general the default hardcopy plot will fill the page on which it is being plotted. If a viewgraph was make of a full page plot, the projected size would overfill most screens. Therefore, it is useful to decrease the default size of the plot a bit. This can be done with the `Viewport` command. The default viewport is `.1 .1` which means the box containing the graph extends from 0.10 to 0.90 of the total physical plotting area. To make a plot half the size, use `View .3 .3`. `View .2 .2` will result in good size for most viewgraphs.

Chapter 3

Aesthetics

3.1 Labels

This chapter will describe the various options available to change the appearance of the plot. One of the most common things to do is to add labels, using the `LAbel` command. To put the label "Time (sec)" on the x-axis, "Distance" on the y-axis, and "My data" at the top of the plot,

```
PLT> LA X Time (sec)
PLT> LA Y Distance
PLT> LA T My data
PLT> P
```

You will notice that only certain PLT commands cause the graphics display to be updated. This allows you to enter several commands quickly without having to wait for the screen to be redrawn after each command. Whenever you want to see what the current graph looks like, you should enter the `Plot` command or just `P`.

There are also *Outer* labels (called `OX`, `OY`, `OT`) that can be used. These outer labels provide a simple way to create labels that need to lie on two lines. For example, the commands

```
PLT> LA X Universal
PLT> LA OX Time (sec)
PLT> P
```

would label the x-axis with two lines of text with the word "Universal" being written above the words "Time (sec)". Now what do you think the following command will do?

```
PLT> LA OT Fun! Fun! Fun!
PLT> P
```

If you try this you will find that only the word "Fun" appears. This is because `!` is the PLT comment character. If you wish to enter a PLT command that contains the comment character, then you must enclose the entire argument in quotation marks:

```
PLT> LA OT "Fun! Fun! Fun!"
PLT> P
```

To remove any label, enter the command with no text; thus,

```
PLT> LA OT
PLT> P
```

will remove the text "Fun! Fun! Fun!" from the graph. The name of the QDP file appears in the `File` position; thus the command `LA F` will remove this name. The timestamp that appears at the bottom of the plot can be removed with the `Time OFf` command and, of course, `Time ON` will turn it back on. In general, you should leave the file name and timestamp in place, as this information is very useful on a hardcopy. Sometimes, when working with a slow plotting device, you will want to speed things up by not plotting any labels. This can be done the `LAbel OFf` command. Of course, you should issue the `LAbel ON` command before making a hardcopy.

Text is drawn with PGPLOT; so the standard PGPLOT escape sequences are used. Hence, the commands

```
PLT> LA T \gx\u2
PLT> P
```

will label the top of the graph with χ^2. The default font is the PGPLOT *Normal font*, which draws rather quickly. For journal quality text, you should override the default font with the `FOnt Roman` command. This will cause all text, including the numeric labels on the axes, to be written in the nicer looking, but slower plotting, Roman font. Use `FOnt ?` to get a list of possible fonts.

It is also possible to place a *numbered label* anywhere in the plot. To see this, try

```
PLT> LA 1 Pos 2 4 LIne -45 "Point at (2,4)"
PLT> P
```

The above command plots LAbel 1 at Position (2,4) with a LIne extending out at an angle of -45° to the x-axis and with the text message "Point at (2,4)". Each attribute can be set individually. Hence, if you decide you don't like the line extending downwards, you could change the angle with

```
PLT> LA 1 LIne 135
PLT> P
```

This leaves the pointing position and text unaffected, but resets the angle of the line (and also the justification of the string).

3.2 Vertical Plots

When you first plotted the `DEMO.QDP` file, two plot groups were plotted on the same panel. It is possible to plot each plot group on a separate panel in a vertical stack. To see this, try

```
$ QDP DEMO
(enter device type)
PLT> Plot Vertical
PLT> Plot
```

The `Plot Vertical` command resets the internal parameters so that each visible plot group will be plotted in a separate panel in a vertical stack. Nothing is replotted until the `Plot` command is issued by itself. This allows you to reset other parameters, without having to wait for a new graph to be drawn.

The y-scale can be adjusted in each panel separately. Hence,

```
PLT> R Y2 0 10
PLT> R Y3 0 50
PLT> P
```

will set the y range of the top panel to be 0 to 10 and of the bottom panel to be 0 to 50. The `R ?` command can be used at any time to display the current ranges. At this point it would be wise to label each plot group. So enter

```
PLT> LA G1 x-axis
PLT> LA G2 group 2
PLT> LA G3 group 3
PLT> P
PLT> R ?
 Current Gap=   .025
Window   XLAB      XMIN        XMAX         YLAB      YMIN        YMAX
   2 : x-axis      .9250    ,  4.075     : group 2     .0000    ,  10.00
   3 : x-axis      .9250    ,  4.075     : group 3     .0000    ,  50.00
PLT>
```

The `R ?` prints out the beginning of each label and therefore, with a good set of labels, it is easy to keep track of what is plotted where.

At this point it is worth pointing out the difference between plot groups, and the rescale parameters. A plot group is a group of associated data points that cannot be displayed in different panels. The `Rescale` command affects the scale of the designated panel. Thus, `R Y2 0 10` will set the y-scale in the second panel to range from 0 to 10. For maximum compatibility with previous versions of PLT, the `Plot Vert` command plots group 2 on panel 2. A command like `LAbel G1` will associate a label with a plot group. Thus if you enter the commands `Xaxis 2`, `Plot Vert`, and then `Plot`, you will find that plot group 2 now determines the x-axis and hence the label "group 2" is now used as the x-label. Plot group 1 is now plotted in the top panel, with the same label "x-axis" which, of course, this is no longer correct.

To undo the effects of the `Plot Vertical` command, you should enter

```
PLT> Plot Overlay
PLT> P
```

The y-axis label is the label of the first plot group to be plotted in that panel. Since now more than one group appears in the panel, this is now longer most appropriate. To override the y-axis label in a given panel, use the `LAbel Y` command. In other words the `LA Y` command can be used to denote all the y plot groups in a given panel, whereas `G1`, `G2`, *etc.* will associate a label with the specified plot group.

3.3 Colors, Lines, and Markers

The default mode of PLT is to plot group 1 with color index 1, group 2 with color index 2, *etc.* The `COlor ?` command can be used to generate a list of the default colors used to plot each color index. The command `COlor 3 ON 2` will cause color index 3 to be used with group 2 is plotted. With the PGPLOT default colors, this means that group 2 will now be plotted in green. It is important to realize that the `COlor` command changes the color index and only indirectly, the color.

Due to historical accident the `COlor` command can be used to prevent plot groups from being plotted. This is because color 0 corresponds to no-color or invisible. Thus `COlor 0 ON 2` will suppress the plotting of group 2. A cleaner way to do this is with the command `COlor OFf 2`. A `COlor OFf` command followed by a `COlor ON` command will restore the original color index. The `R Y` (with no arguments) command only

uses plot groups that are visible to determine the default scale. For example, assume you are working with 6 plot groups and the values of groups 1 to 5 all lie in the range of 0.0 to 1.0, whereas the values in group 6 all lie near 100,000. For this example, the commands

```
PLT> COlor OFF 6
PLT> R Y
```

would redraw the graph, and the default y range will lie between 0.0 and 1.0.

In the above examples, PLT drew a line between the points being plotted. If you wish to display the plot with markers, then you should turn on the plotting of markers with

```
PLT> MArk ON
PLT> P
```

For this example, the line connecting the various points disappears and only markers will be drawn. PLT draws a line when (a) all attributes (`LIne`, `MArker`, and `Errors`) are `OFF` or (b) the line attribute is `ON`. Thus if you want both the connecting line and markers to appear, then you need to turn on the `LIne` attribute with

```
PLT> LIne ON
PLT> P
```

The command `MArker Size 2` can be used to make the markers twice as big. The default marker style for all plot groups is type 2 as this marker plots very quickly. To change the style of the marker, try `MArker 9 ON 2` to use marker style 9 when plotting group 2. The command `MArker ?` will display a table of marker styles.

3.4 Log Scale

It is also possible to plot the data on a log scale. To do this, type

```
PLT> LOg Y
PLT> P
```

Use `LOg X` to use a log scale on the x-axis. The `LOg OFf` command will turn off the log scale on both the x- and y- axes. Note: Using `LOg` does not cause the data to be altered, only the appearance of the plot changes. If the lower limit of the scale being logged is negative or zero, then PLT will rescan the data searching for the smallest positive value, and make that the lower limit.

You should also be aware of the fact that the size of the gap, created by the `GAp` command is affected by log scale. Thus for a non-zero gap, the sequence `R X` followed by `LOg X` produces a different range than `LOg X` followed by `R X`. In the first case, the data minimum and maximum values are found, and then gap added in linear space. Applying the `LOg` command does not change this scale. In the second case, the scale is first logged, then the data minimum and maximum values are found. At this point the correct gap for a log plot is added.

Chapter 4

Fitting

4.1 Errors

This section describes a QDP file that contains errors and how to control plotting of those errors. The next two sections will describe how to define a model, find the best fitting parameter values, and then estimate the uncertainties on the parameter values. Although the examples will be based on the QDP file containing errors, it is possible (and sometimes better) to fit data without errors.

You should now create a `DEMO1.QDP` file that contains the following:

```
READ Serr 1 2
LAbel X Time
LAbel Y Distance
 1.0  .25   1.24  .3
 1.5  .25   1.86  .3
 2.0  .25   3.76  .3
 4.0 1.75  16.43  .3
 7.0 1.25  49.06  .3
```

The first line in this file is not a PLT command but rather a QDP command. The QDP `READ` command is used by QDP to tell PLT which vectors contain errors. In this case the READ command tells QDP that vectors 1 and 2 will have symmetric errors; hence, columns 1 and 2 contain data and errors for vector 1, and columns 3 and 4 contain data and errors for vector 2. Following the QDP command are two PLT commands that will be passed to the PLT program and executed before the graph is drawn. Including PLT commands in the QDP file provide a way to override built-in defaults and/or to add labels to the graph. Data lines occur after all the command lines. To read and plot this file, use

```
$ QDP DEMO1
(enter device type)
PLT>
```

The graph that looks like figure 4.1 should now appear. When you plot data containing errors, the error attribute is `ON`, and the errors plotted. As described in section 3.3, the line will no longer appear connecting the data. If you want to see that line, then should use `LIne ON` to explicitly switch on the line. To suppress plotting of the errors use,

```
PLT> Error OFf
PLT> P
```

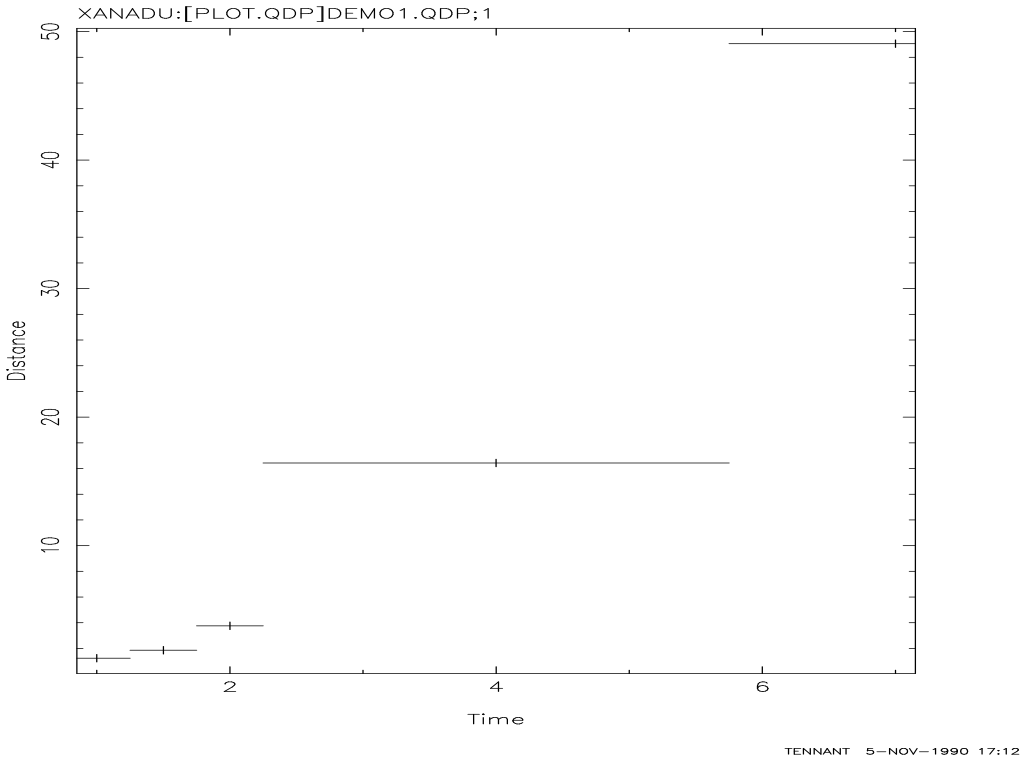

Figure 4.1: The default appearance of the `DEMO1.QDP` file.

This causes the error bars not to be plotted; once again the line connecting the points appears. You should now enter

```
PLT> LIne Step
PLT> P
```

to produce a stepped-line plot. Using `Error ON` at this time will cause both the stepped line and the errors to be plotted. This is because the `LIne Step` command sets an internal flag that a line should be plotted and the `Error ON` command sets another flag to plot errors. The command `LIne OFf` will turn off the plotting of the (stepped) line. The plotting of a line, errors and markers can all be turned on or off for each vector independently. You should see the `LIne`, `Error` and `MArker` commands, in Appendix B, **PLT Command Summary**, for more information.

4.2 Fitting

This section requires the `DEMO1.QDP` file described in the previous section. Before you can fit data, you must first define a model. First, read in the data and define a constant model with

```
$ QDP DEMO1
(enter device type)
PLT> MOdel CONS
```

At this point, you will be prompted for the default initial value for the constant. Enter Return to use the default, and at the `PLT>` prompt, type `Fit`.[1] When `Fit` runs, it first tells you which plot group is being fitted and the range over which data are being fitted. It is important to realize that if you have used `R X` to rescale the x-axis so that some points are outside the range plotted, then these points would not be included in the fit. You cannot exclude points using the `R Y` command. (This is intended to prevent cheating.) You will next see the message "Fitting 5 points in a band of 5". This informs you that there are 5 points in the current x-range. In order to execute faster, the FIT routine resets the minimum and maximum of the array, to achieve the smallest range possible that includes all points in the x-range, and so the "band of 5" output informs you how big this minimum range is. Next the FIT routine prints the current parameter values (1.00000 in this case). The program then prints the current value of the weighted variance `W-VAR`. If you have errors on your data, the weighted variance is χ^2; for no errors, `W-VAR` is just the variance. The number in `()` is $\log \lambda$ and is for the expert's use.

The *CURFIT* routine will terminate when the change in χ^2 or, for an unweighted fit the relative change in the variance, is less than 0.05. If this condition has not been met after 10 iterations, you will be prompted "`Continue fitting? (n)`". Answer `Y` to continue or `N` to terminate. If you are are fitting in background or batch mode, then you should always leave a blank line after the `Fit` command. Thus if `Fit` does not terminate, the "`Continue fitting? (n)`" question will read the blank line with the default answer of no and terminate. If the fit does terminate, PLT will see the blank line, and ignore it. When *CURFIT* terminates the current parameter values are again printed and this model is drawn on the current plot.

For the above, the total variance is 18323 and hence a CONS does not look like a very good model. Let's try a more complicated model with

```
PLT> MOdel CO LI QU
```

to include constant, linear and quadratic components. Again you can default on all the initial values. When you type `Fit`, you should find that `W-VAR` has decreased to 4.23. This is clearly a better fit.

To generate a list of all possible built-in components, use the `MOdel ?` command. To get a description of what a component does, use the `HElp MOdel` command followed by the component name. If you can not construct your model from the built-in components, then you can create additional components. A COD file can be used to define a sophisticated component. COD files are ASCII text files that contain functions written in a Forth-like computer language. Chapter 7 and Appendix A describe COD in some detail. If your component is too complicated for COD, or you don't like using COD, then you can create a Fortran function that can be used as a new component. The next chapter will describe how to create this function `UFNY`, and the supporting routines to replace the built-in `DEMO` component.

It is possible to save the current model to a disk file using the `WModel` command. For example,

```
PLT> WModel DEMO1
```

[1] The *FIT* subroutine minimizes χ^2 using a modified version of Bevington's *CURFIT* subroutine. Bevington's book *Data reduction and Error Analysis for the Physical Sciences*, published by McGraw-Hill in 1969, is an excellent introduction to statistics. Anyone interested in a detailed understanding of how CURFIT works should consult this book.

will create a DEMO1.MOD file. To read this model back into PLT use the command MOdel @DEMO1. Model files can be printed out to make a hardcopy of the current parameter values. If you do not enter a file name with the WModel command, then the model is written to your current terminal screen.

4.3 Parameter Uncertainties

The Uncertainty command can be used to estimate the uncertainties in the parameter values.[2] To try this, you should first fit the data in the DEMO1.QDP file to a CO LI QU model, as described in the previous section. Now enter the command

```
PLT> Uncertain 1
```

The program will now change the value of parameter 1 by a small amount and recompute χ^2. At each step, the delta parameter value and the $\Delta\chi^2$ are printed out. For complicated models it may take many steps before the desired value of $\Delta\chi^2$ is found. The program considers both positive and negative delta parameter values. The default value of $\Delta\chi^2$ is 2.7 which corresponds to the 90% confidence range for a single parameter.

With the DEMO1.QDP file you will find that both parameter 1 and 2 are consistent with zero. To see if they can be eliminated, try the following:

```
PLT> Newpar 1,0,-1
PLT> Newpar 2,0,-1
PLT> Fit
```

The first command resets both the VAL and SIG terms of parameter 1 to be 0.0 and -1.0, respectively. A SIG of -1.0 means that the parameter is frozen and hence not allowed to change. Note: The command Newpar 1,,-1 would have frozen parameter 1 at its current value. The second line freezes the value of parameter 2 to be zero. The results of the Fit reveal that χ^2 has increased by 0.55 and the F-statistic or a likelihood ratio tells us that these two components were not required by the model.

The Uncertainty command is fairly robust but on occasion can have difficulties. Sometimes, Uncertainty will find a new minimum value of χ^2. This causes the search to be stopped and the parameter values to be reset. At this point, you should reissue the Fit command to locate precisely the new minimum. Sometimes, Uncertainty will be unable to locate the requested value of $\Delta\chi^2$ after 10 tries. At this point the message UNCERT--Give up. is printed. It will be up to you to decide if the error has been correctly calculated. Finally, the Uncertainty command uses the SIG value to estimate the location of the error. If this number is greatly in error, then Uncertainty will be start it's search in the wrong place. If this occurs then it is sometimes possible to adjust SIG to be a more accurate estimate, before issuing the Uncertainty command. It is also possible that the SIG is inaccurate because the true minimum has not been found and further fitting is needed.

[2] Uncertainties in parameter values are estimated using the method described in "Parameter Estimation in X-ray Astronomy", by M. Lampton, B. Margon, and S. Bowyer, in *Astrophysical Journal* (1976) **208**, 177.

Chapter 5

Miscellaneous

5.1 PLT Command Files

PLT commands can also be entered *via* a command file. For example, if you often enter the sequence of commands `FOnt Roman` followed by `CSize 1.3`, then you could create a file called `NICE.PCO` that contains the lines

```
FOnt Roman
CSize 1.3
```

To execute these commands inside PLT, all you need to type is

```
PLT> @NICE
```

(A default file extension `.PCO` is assumed.) Thus command files provide a way to enter several and/or complicated commands easily.

Note that the reference to a command file is a legal PLT command that can appear in a QDP file. Since this is a PLT command, QDP itself will not open and read the command file. Hence, QDP commands and data lines cannot be entered *via* a command file. Command files serve two important uses in QDP files. First, they provide a way to enter the same set of commands to several files. Second, for long data files, editing the QDP file can be tedious. Hence, you can edit it once to enter a reference to the command file. Thereafter, whenever you want to change the PLT command list, you only need to edit the command file.

PLT searches up to three different directories for the specified indirect command. The current directory is always searched first. If the file is not found in the current directory then PLT tries to translate the logical name (under VMS) or environment variable (under UNIX or DOS) called MY_XCOMS. If MY_XCOMS has been defined, then PLT searches the specified directory. If the file still has not been found then PLT searches the `XANADU:[LIB.XCOMS]` directory. This three level search allows you to create system-wide files, user-wide files, and directory specific files. For example, many locations create a file `HARD.PCO` in the `XANADU:[LIB.XCOMS]` directory that (1) creates a hardcopy file and (2) spools the file to the printer (done using the `$` command to spawn a job to spool the plot to the printer). This then allows all users on that system to use

```
PLT> @HARD
```

to immediately print a hardcopy. If you do not like something about the existing `@HARD` command then you can easily create a new private version of this command. First copy the file to one of your own directories, modify the file, and define MY_XCOMS to contain

the name of the directory containing the new version. Once this has been done, PLT will find and run your version of the command instead of the system installed version.

It is possible to use parameters with indirect command files. The parameter values are entered on the same line that opened the indirect command file. Thus,

```
PLT> @test one two three
```

would cause plt to open and read the `TEST.PCO` file with three parameters "`one`", "`two`", and "`three`". If `n` is a number then the sequence **%n%** will be replaced with the nth parameter. For the above example, **%1%** will be replaced with '`one`', **%2%** with '`two`', *etc.* The following illustrates a possible indirect file that could use up to three parameters:

```
LABel X %1%
LABel Y %2%
LABel T %3%
```

If you fail to enter all three parameters, then **%n%** will be replaced with a null string for the unentered parameters.

It is possible for one indirect file to call another indirect file and pass in parameters. Thus,

```
@deeper first %2% %3%
```

is a valid line in an indirect command file. In this example, the first parameter is "`first`", whereas the next two parameters will be set equal to parameters 2 and 3 of the current script. Also quotes can be used to denotes a single parameter with embedded spaces, or other 'magic' characters. Thus the line,

```
@file "This is all one" two three
```

contains three parameters, and the first parameter is the string '`This is all one`'.

5.2 Version Control

New features are constantly being added to PLT, and so it is important track of these changes. There are three places where changes are noted. First, the PLT `VErsion` command can be used to identify the date of the most recent change to version of PLT linked into the program you are using. If certain commands do not appear to work then you should check this number. Often you will find that the program has not been linked for a while and as a result the command that you are trying to use was added after the last link.

The second place version numbers are recorded is in the on-line help file. The `HElp VErsion` command will list all recently added new features and when they were made. A serious attempt is made to ensure that on-line help is updated as the software is modified. For best results on your system, you should also update the on-line help every time you update PLT itself. However, there is no requirement for these two version numbers to match. Thus, when you install a new version of PLT it is not necessary to immediately relink all software that uses it.

Finally the printed manual is updated about once a year. Therefore, the printed manual can be slightly out of date.

Chapter 6

Fortran interface

6.1 Programming PLT

After using the QDP/PLT software for a while, some people would like to see more sophisticated features such as the ability to read binary files, or to add different vectors together. Although the author is always willing to take suggestions (and even to implement some of these suggestions), the PLT design goal is to implement new features in as a general manner as possible. Thus if you have a need to read a particular file format, or to manipulate data in a particular manner, you should implement your own front end to the PLT subroutine. This is simple to do since the QDP program cleanly separates reading of the file from actually calling the PLT routine.

This chapter describes how to call the RDQDP and PLT subroutines. Also listed is the complete source code for the QDP program. Although QDP can be used as an example of how to call PLT, it is perhaps too simple. Therefore the DEMO Fortran program more clearly shows how to do this. Finally there are instructions on how to create your own user defined function that when linked with the QDP/PLT software can be used with the `Model` and `Fit` commands.

Although PLT uses several other internal routines, you are discouraged from directly using these routines in your code. This is because PLT continues to evolve, and there is no way that the author add the functionality required without the ability to modify the internal interfaces. There are no plans to modify the calling sequence for all the routines described in this chapter.

6.2 Subroutine RDQDP

The calling sequence for the RDQDP subroutine is:

```
      SUBROUTINE RDQDP(ICHAT, LUNIN, CNAM, Y, MXPTS, IERY, MXVEC,
     :   NROW, NPTS, NVEC, CMD, MXCMD, NCMD, IER)
      INTEGER   MXPTS, MXVEC, MXCMD
      CHARACTER CNAM*(*), CMD(MXCMD)*(*)
      REAL      Y(MXPTS)
      INTEGER   IERY(MXVEC)
      INTEGER   ICHAT, LUNIN, NROW, NPTS, NVEC, NCMD, IER
C---
C Opens and reads a QDP file.
C---
C ICHAT     I    >10 means print comment lines, >0 print row/col info.
C LUNIN     I    <>0 means file already open on LUN.
C CNAM      I/O  File name.
C Y           O  The data array
C MXPTS     I    The actual size of the Y array.
C IERY        O  The PLT error flag array
C MXVEC     I    The actual size of the IERY array
C NROW        O  Maximum number of rows that the file could contain.
C NPTS,NVEC   O  Needed by PLT
C CMD         O  Command array (MXCMD input dimension).
C NCMD        O  Number of commands read
C IER         O  =-1 if user entered EOF, =0 file read, =1 no file read.
```

There are several ways to specify a file to be read by RDQDP. RDQDP will go through the following steps to determine what file to read. Once a file has been determined the remaining steps will be skipped. Specifically RDQDP will do the following:

- If the variable LUNIN is non-zero then RDQDP will assume that the input file has already been opened and is attached to the specified unit number.
- If the variable CNAM is non-blank, then RDQDP opens a file with the specified name.
- At this point it is necessary to obtain a file name from an external source and the parser is called to handle this. If this is the first time the parser has been called in the current program, an attempt will be made to read the command line. If a QDP file name is found on the command line, then that file is opened.
- If no file name could be found, or the file could not be opened, then RDQDP will prompt the user for an input file name. If the user enters an end-of-file (^Z under VMS, or /* under all systems), then RDQDP will exit with IER=-1. If the user enters a blank line for the file name, RDQDP will exit IER>0. Of course, if the user enters a valid file name, then that file is opened, and IER will return a value of 0.

Once a file has been opened, and if MXCMD>1, RDQDP will add a LAbel F command to the CMD array that contains the name of the file actually opened. Of course, if the file

contains a `LAbel F` command, then that command will overwrite the label that RDQDP creates.

`ICHAT` is the 'chatter' flag. If `ICHAT`>10 then RDQDP will display lines that have `!` in the first column, on your terminal screen. Displaying these lines, provides a useful way to confirm that RDQDP has opened the correct file. Such comment lines are completely ignored, and the comments will be removed from any other line containing a comment. RDQDP examines the beginning of each line and if the line contains a QDP command, RDQDP proceeds to interpret the command and set the appropriate variables to be passed to PLT. If the line starts with a PLT command and `NCMD`<`MXCMD`, then RDQDP will increment `NCMD` and add the line to the `CMD` array. For lines containing data, RDQDP interprets the line into real numbers and stores these numbers in the `Y` array.

The RDQDP routine does not open and read any indirect command files, but just stores the command in the `CMD` array. Therefore you cannot use an indirect command file to contain the data array. Since the calling program determines the size of the `CMD` array it is sometimes useful to store all PLT commands in an indirect command file and to add one line to the QDP file to read the indirect file. When PLT reads an read indirect file it will accept command lines up to 250 characters long, and there is no limit on the number of lines that can be read.

When RDQDP reads the first data line, it determines the number of columns in that line. Based on this number of columns, and the size of `MXPTS` passed in, RDQDP proceeds to calculate the maximum number of rows that would fit into the `Y` array. If the `ICHAT`> 0, RDQDP will then display on the terminal, the number of columns, the numbers of vectors (calculated from the data from in any `READ` lines), and the maximum number of rows.

6.3 Subroutine PLT

The calling sequence for the PLT subroutine is:

```
      SUBROUTINE PLT(Y, IERY, MXROW, NPTS, NVEC, CMD, NCMD, IER)
      REAL      Y(*)
      INTEGER   IERY(*), MXROW, NPTS, NVEC, NCMD, IER
      CHARACTER CMD(*)*(*)
C---
C General plot subroutine.
C---
C Y(*)      I    The data array.  The array should be dimensioned
C                Y(MXROW,MXCOL) where MXROW and MXCOL are the actual
C                sizes of the arrays in the calling program.
C                MXCOL=NVEC+NSERR+2*NTERR  where NSERR is the number
C                of vectors that have symmetric errors and NTERR
C                is the number of vectors that have two-sided errors.
C IERY(*)   I    =-1 plot errors as SQRT(Y)
C                = 0 no errors.
C                =+1 explicit symmetric errors.
C                =+2 for two-sided errors
C MXROW     I    The actual first dimension of the Y array.
C NPTS      I    The number of points to plot (NPTS<=MXROW).
C NVEC      I    The number of vectors to be plotted.
C CMD(*)    I    Array of commands.
C NCMD      I    Number of commands.
C IER         O  Error flag, =-1 if user entered EOF, =0 otherwise.
```

It is important to remember that the variable NVEC does not refer to the number of columns of data but rather the number of vectors. Each vector must have one entry in the IERY array that describes the type of error on that vector. Depending on the type of error, each vector can be composed of one, two, or three columns of data. To calculate the number of columns needed by the vectors, let NSERR be the number of vectors with symmetric errors (IERY(I)=1) and NTERR the number with two sided errors (IERY(I)=2). The total number of columns MXCOL will be given by MXCOL=NVEC+NSERR+2*NTERR.

The variable MXROW contains the physical first dimension of the Y array. Thus the calling program should dimension Y to be (MXROW,MXCOL) or the Fortran equivalent (MXROW*MXCOL). The variable NPTS contains the number of rows that contain valid data. All rows from NPTS+1 to MXROW will be ignored. When PLT starts it will execute NCMD lines from the CMD array. Any valid PLT command can be entered into this array. For example, one line could contain a reference to an indirect command file, and this would cause PLT to execute all commands found in this file. If the command list contains the EXit command, then PLT will exit when this command executes and any commands following the EXit will be ignored. Since PLT does not actually plot any data until all the commands are executed, it is a good idea to precede an EXit with a Plot command, since that will force a plot to be produced.

If PLT exits normally, *i.e.*, with the the EXit command, then IER is set to zero. If the user enters an end-of-file then PLT exits with IER<0.

6.4 The QDP program

The complete source code for the QDP program is:

```
C Program QDP, the Quick and Dandy Plotter.
C Reads and plots a QDP file.
C---
C [AFT]
C---
      INTEGER   MXPTS, MXVEC, MXCMD
      PARAMETER (MXPTS=131072)
      PARAMETER (MXVEC=64)
      PARAMETER (MXCMD=50)
C
      CHARACTER CMD(MXCMD)*100
      CHARACTER CNAM*72
      REAL      Y(MXPTS)
      INTEGER   IERY(MXVEC)
      INTEGER   ICHAT, IER, LUN, NCMD, NPTS, NROW, NVEC
C---
  100 CNAM=' '
      ICHAT=0
      LUN=0
      CALL RDQDP(ICHAT, LUN, CNAM, Y, MXPTS, IERY, MXVEC,
     :   NROW, NPTS, NVEC, CMD, MXCMD, NCMD, IER)
      IF(IER.NE.0) GOTO 900
      CALL PLT(Y,IERY,NROW,NPTS,NVEC,CMD,NCMD,IER)
      IF(IER.LT.0) GOTO 100
C---
  900 CONTINUE
      END
```

The QDP program calls the RDQDP subroutine to read the QDP file, and then passes the data read to PLT. The parameter statements show that this version can read a file containing up to 131,072 numbers, up to 64 different vectors, and up to 50 PLT command lines. RDQDP sets creates array dimensions to make maximum use of the data array. For example, if you read a file containing two columns, then you could read up to 65536 rows of data. If the file contains 64 vectors and none of the vectors contains errors *i.e.*, there are 64 columns of numbers, then the maximum number of rows will be 2048. If, however, all 64 vectors contain two-sided errors, then only 512 rows can be read. Each PLT command line can be at most 100 characters long.

QDP sets both `CNAM=' '` and `LUN=0` to force RDQDP to prompt for a QDP file name. If the file is opened, then RDQDP proceeds to read the file, and initializes all the variables needed by the PLT routine. If RDQDP has set `IER=0` then some data has been read and hence the PLT routine is called.

PLT interprets the PLT commands and plots the data. If the user enters an end-of-file character at the `PLT>` prompt, PLT exits with `IER=-1`. This causes the QDP program to loop back and call RDQDP again. For a normal exits, `IER=0`, the QDP program quietly exits.

6.5 The DEMO program

The file XANADU:[PLOT.QDP]DEMO.FOR contains a simple Fortran program that creates the necessary arrays and then calls the PLT subroutine. The complete source code for the DEMO.FOR program is:

```
C---
C DEMO.FOR demonstrates how to call PLT from a Fortran program.
C---
C [AFT]
C---
      INTEGER   MXROW, MXCOL, MXVEC, MXCMD
      PARAMETER (MXROW=200, MXCOL=3, MXVEC=2, MXCMD=10)
      CHARACTER CMD(MXCMD)*72
      REAL      Y(MXROW, MXCOL)
      INTEGER   IERY(MXVEC), NVEC, NPTS, NCMD, IER
      INTEGER   I
C---
C Create two vectors.  The first vector will contain the X locations
C and a symmetric error (with constant value of 0.5).  The second
C vector will contain X*X and no error.
      NVEC=2
      IERY(1)=1
      IERY(2)=0
      NPTS=100
      DO 190 I=1,NPTS
         Y(I,1)=I
         Y(I,2)=.5
         Y(I,3)=Y(I,1)*Y(I,1)
  190 CONTINUE
C---
C Now add a couple of commands, to make plot look nicer.
      CMD(1)='LAB X Time (sec)'
      CMD(2)='LAB Y Distance (m)'
      CMD(3)='LAB T Made with DEMO.FOR'
      CMD(4)='LINE STEP 2'
      NCMD=4
C---
C Call the PLT subroutine.
      CALL PLT(Y, IERY, MXROW, NPTS, NVEC, CMD, NCMD, IER)
      END
```

DEMO.FOR was written as an example to show how the various parameters are initialized before calling PLT. In the program NVEC=2 tells PLT to expect two vectors; IERY(1)=1 tells PLT that the first vector contains symmetric errors and, hence, is composed of two columns; and IERY(2)=0 tells PLT that the second vector does not have errors. The DO 190 loop fills 100 points of these two vectors. The Y array is large enough to contain up to 200 points. The first column of the Y array contains the x-value, which run from 1 to 100; the second column contains the errors (constant value

0.5); and the third column contains x^2. After the `Y` array is initialized, the `CMD` array is initialized with four PLT commands. The first three commands define labels, and the last command creates a stepped-line plot.

The file `XANADU:[PLOT.QDP]DEMO.COM` will compile and link the `DEMO.FOR` program on a VMS system. This file can be used as an example for linking other routines that call PLT. It is necessary to link with both the XANLIB library and also the PGPLOT graphics library.

6.6 A user function

The calling sequences for the four subroutines required to create a user component are:

```
      SUBROUTINE UINFO(IPAR, CNAME, NPAR)
      INTEGER   IPAR, NPAR
      CHARACTER CNAME*(*)
C---
C IPAR    I    The parameter number.
C CNAME     O  The name of the parameter IPAR.  Note if IPAR=0, then
C              -return the name of the model.
C NPAR      O  The number of parameters in your user model.
C---
C*********
      SUBROUTINE ULIMIT(PVAL, PLIM, NT, NPAR)
      REAL      PVAL(*), PLIM(3,*)
      INTEGER   NT, NPAR
C---
C PVAL(*)   I/O  The current parameter values
C PLIM(1,*) I    If <0 then the corresponding parameter is frozen
C NT        I    Pointer to first parameter value in array PVAL(*)
C NPAR      I    Number of parameters
C---
C*********
      REAL FUNCTION UFNY(X, PVAL, NT, NPAR)
      REAL      X, PVAL(*)
      INTEGER   NT, NPAR
C---
C X       I    The current X value
C PVAL    I    The current parameter values
C NT      I    Pointer to first parameter value in array PVAL(*)
C NPAR    I    Number of parameters
C---
C*********
      SUBROUTINE UDERIV(X, PVAL, PLIM, DERIV, NT, NPAR)
      REAL      X, PVAL(*), PLIM(3,*), DERIV(*)
      INTEGER   NT, NPAR
C---
C X       I    The current X value
C PVAL    I    The current parameter values
C PLIM    I    The constraints array
C DERIV     O  The calculated derivative
C NT      I    Pointer to first parameter value in array PVAL(*)
C NPAR    I    Number of parameters
C---
```

The file `XANADU:[LIB.UFNY]UFNYDEMO.FOR` contains the source code for the built-in `DEMO` user component. You should copy that file and use it as a template for any file that you create.

When FIT starts, it calls UINFO with `IPAR` set equal to 0 to get the name of the user component and the number of parameters. This component name will be included in the names of the built-in components, and therefore, should not match any existing component name (such as `CONS`, `LINE`, etc.) If the user component is selected, then UINFO will be called for each parameter to get the name of that parameter.

ULIMIT is always called after any parameter values have been changed and before UFNY is called. The purpose of ULIMIT is two-fold. First, it should check the parameter values in `PVAL` and adjust any that may cause a problem in UFNY (for example, if UFNY divides by a parameter value, then ULIMIT should ensure that the parameter does not equal zero). Second, ULIMIT can be used to set up any initial data that UFNY needs. Since, UFNY is often called many times with the same parameter set, this can result in a speedup. The parameter values are stored in `PVAL(NT)` to `PVAL(NT+NPAR-1)`. The `PLIM` array contains `SIG`, `PLO`, and `PHI`. If `PLIM(1,I)` is less than zero, then that parameter is frozen and you should not adjust the parameter value. Also, if `PLIM(2,I)`<`PLIM(3,I)`, then an effective range is active and you should not adjust a parameter outside that range.

UFNY is the function that actually calculates user component at location `X` with parameter values given by `PVAL`.

UDERIV should calculate the derivative of the UFNY function with respect to each parameter. The version contained in `UFNYDEMO.FOR` evaluates the derivative numerically and hence you may be able to use it without modification. If you use that method you should try to scale the problem so that parameter values are in the range .1-100, values outside this range work, but the convergence can be slower.

If `PLIM(1,I)=-1` then that parameter is frozen and hence you do not need to calculate the derivative. If `PLIM(1,I)<-1` then the parameter has been set equal to another parameter and you should calculate the derivative in the normal manner (the FIT routine assumes that the derivative has been correctly calculated).

If you able to compute the analytic derivative of your function with respect to the parameter values, then you should use it, as an accurate derivative can greatly improve the fitting process. NOTE, slow convergence is most often due to the derivative being incorrectly calculated. If you find that χ^2 drops slowly, and that FIT is unable to precisely locate the minimum, then you should carefully check both your equations and the UDERIV implementation for typical errors, such as an incorrect sign.

Once you have a working function, you should test it in PLT. Use the `MOdel ?` command to see if your component is listed. If not make sure you have linked a new version, and that your are running that new version. Next define a model that is composed only of your new component, and enter a resonable set of parameters. Do not attempt to fit at this time, but rather just plot the data and model. Use the `Fit Plot 200` command to ensure that the function is evaluated at 200 points over the visible range. Is the plotted function what you expected? If it is not then you should carefully examine your code.

Once the function is doing what you expect, then you can try to fit it. If certain parameter values can cause a program crash, then you should write a version of ULIMIT that prohibits these values.

Chapter 7

COD

7.1 Introduction

The `COD` program has been designed to fill two roles. First, it can be used like a programmable calculator. In this mode you can use the computer to do simple calculations (on days that your calculator is down). Second, it is designed to assist in developing and testing COD functions that can be used as components in PLT models.

This chapter will assume that you want to create a COD file that can be used with PLT. If you have no previous experience with COD, then you should start by running the `COD` program and learning how to use the stack and various built-in functions. (In COD, functions are sometimes called *words*.) Next you should create and use some simple *colon definitions* within `COD` itself. Colon definitions are the way one creates new functions. COD files contain ASCII text in the same form as you would type in interactive mode. A file that can be used as a model component by PLT is nothing more than a COD file containing a colon definition and supporting code. The `COD` program provides tools for the reading and testing of functions contained in COD files.

7.2 Interactive mode

The best way to learn about COD is to run the `COD` program and experiment. This can be done with

```
$ COD
Type HELP for help.

COD>
```

When COD starts, it first prints information on how to get help, followed by a blank line. The blank line actually displays the contents of the stack, which is initially empty. Finally, you get the "`COD>`" prompt. At this prompt you can type `HElp` to obtain interactive help on the various commands and how to use them.

The first thing you will want to do is to enter a number into the stack. This is done by typing the number and then pressing the Return key. For example, to enter the number `2` into the stack,

```
COD> 2
 2.0
```

COD echos the stack and then returns the COD prompt. (In this documentation the final prompt is not shown.) To execute a simple mathematical function enter, all the numbers required by the function and then the function itself. The following sequence shows how to multiply the previously entered `2` by the number `3` to obtain `2*3`:

```
 2.0
COD> 3
 2.0 3.0
COD> *
 6.0
```

With COD it is not necessary to enter one token (number or function) per line. Tokens may be entered, separated by spaces, on a single line. Hence, to divide the result of the previous calculation by `0.5`, enter

```
 6.0
COD> .5 /
 12.0
```

COD contains several commands to manipulate the stack. Thus `SWap` will swap the top two numbers on the stack, and `DUP` will duplicate the top number on the stack. When using COD interactively, you will sometimes wish to clear out the stack. The can be done using the `ABOrt` command. Thus,

```
 12.0
COD> ABOrt
```

and the blank line indicating an empty stack will again appear just before the following COD prompt. There are a large number of built-in COD functions. To obtain a list of the functions, you may use the `List Dictionary` command. If you see a function and would like more information on what it does, you should use the `HElp Dictionary` command. For a complete list of built-in COD commands, consult Appendix A.

7.3 Colon Definitions

When running COD interactively, it is sometimes necessary to enter the same sequence of tokens several times. For such cases, you should create a colon definition that contains the sequence. A colon definition consists of a colon `:` , followed by the function name, followed by the sequence of COD functions that you wish to execute when the function name is typed, and terminated with a semi-colon `;` . For example, although there is no built-in COD function to square a number, you can create one with

```
COD> : X2 DUP * ;
```

which will have the effect of multiplying the top number on the stack by itself. After you have defined `X2`, it may be used in exactly the same way as any built-in function; thus,

```
COD> 3.0 X2
 9.0
```

A previously defined colon function may be used in the definition of a new colon function. An `X3` function, for example, can be constructed from the `X2` function with

```
COD> : X3 DUP X2 * ;
 9.0
COD> 3.0 X3
 9.0 27.0
```

The name of a colon function is not allowed to match the name of any built-in function or other colon function. Hence, a colon function cannot be used to redefine the action of any existing COD keyword.

It is possible to enter a multi-line colon definition interactively. While in the midst of a multi-line colon definition, the stack will not be printed just before the COD prompt. The following example shows one way to enter a colon definition that prints the integers from one to five:

```
COD> : COUNT5
COD>   5 1 FOR
COD>          I .
COD>       LOOP
COD> ;
 9.0 27.0
COD> COUNT5
 1.0
 2.0
 3.0
 4.0
 5.0
 9.0 27.0
```

The last line, just before the next COD prompt, is the stack. This allows us to verify that the original stack has been changed, and therefore, `COUNT5` is not altering the stack.

7.4 COD Files

COD provides a way to read commands from a disk file. These files contain the same commands that you would enter *via* the interactive mode. Commands not contained in a colon definition will execute as the file is read. In order to use a COD file as a model component in PLT, it is necessary that the file contain at least one colon definition and it is the last colon definition that will be called when the component is evaluated. As an example of a COD file, assume the file `LINE.COD` contains the following lines:

```
! COD program to calculate a line.
! P1 + P2*X
: LINE  P1 X P2 * + ;
```

All lines that begin with '!' are considered comment lines and are ignored by COD. The third line contains the program itself. `P1` and `P2` refer to the parameters that will be adjusted to minimize χ^2. When these words execute, they will load the value of the corresponding parameter into the stack. When writing COD programs that use parameters, you must use consecutive numbers starting with one — *i.e.*, do not leave any holes in the sequence. The keyword `X` is used to push the current value of x into the stack.

It is also possible to use the COD program to read and test the code found in a COD file. The following example demonstrates how this can be done:

```
COD> GET LINE  ! Read the test file, note comment lines are echoed.
 ! COD program to calculate a line.
 ! P1 + P2*X
 NTERMS= 2
COD> NEW 1 2.  ! Set parameter 1 to 2.0

COD> NEW 2 1.  ! Set parameter 2 to 1.0

COD> 5         ! Place the number 5.0 in the stack
 5.0
COD> RUN       ! Run the program with an X value of 5.0
 7.0           ! The final result
```

The `RUN` command reads the top number on the stack, makes it the x value, clears the stack, and then runs the last program in memory. All these steps ensure that COD is in the same state as it will be when called from the PLT routine.

The `Single` step command can be used to debug a COD function. In the above example, instead of typing `RUN`, you could have entered `Single Init`. This would have read the top number in the stack, made it the x value, cleared the stack, and then executed the first step in the `LINE` colon definition. When using `Single` step, COD echos a line that contains three columns of information. The first column is the memory location that is about to be executed. The second column contains the encoded command which can be ignored. The third column is the decoded command that is to be executed. When taking single steps, the stack is still be printed just before the COD prompt appears. Hence, you can watch each step and its effect on the stack.

Code not contained in a colon definition will execute as the COD file is being read. Assume the `FUNC.COD` file contains the following lines:

```
 VAR 2PI
 2 PI * 2PI STO
 : FUNC X 2PI RCL * P1 / COS ;
```

While this file is being read, the variable `2PI` is created and loaded with the value of 2π. The function `FUNC` can now access and use this variable.

7.5 Other Stack-Oriented Languages

People who have used the Forth, Postscript, and/or HP calculators will recognize certain similarities with COD. This is partly by accident, since all these languages were designed to solve the problem of making a very fast interpreted language. Given the similarity, it would be pointless for similar functions to be implemented differently in COD. Although there is no standard stack-oriented language, when compared to HP calculator language, and even to Postscript the deficiencies/limitations of Forth are serious. In addition, it is the author's opinion that more people know about HP calculators and Postscript, then about Forth. For these reasons, Forth will no longer be considered to be a model for COD. It is the intention of the current author to pattern new COD functions after existing functions from other languages. Currently, HP calculator language, as implemented on the HP48, is the most powerful such language and will be examined first for models of new COD functions.

The QDP/PLT User's Guide

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