You should replace this cover sheet with one made by running SM and saying `load cover cover`.

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1 Introduction

SM is still evolving slowly, and this documentation may not be true, helpful, or complete. In order of increasing plausibility, information may be obtained from the HELP command, this document, the authors, and the source code. RHL is prepared to guarantee that the executable code has not been patched.

If you find bugs, (reasonable) features that you want, wrong documentation, or anything else that inspires you please let us know. At least under Unix the macro `gripe' should be a convenient way to send us mail. Please also send us any clever macros that you would like to share.

Next a disclaimer: SM is copyright ©1987, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000 Robert Lupton and Patricia Monger. This programme is not public domain, except where specifically stated to the contrary, either in the code, or in the manual. If you have a legally acquired copy you may use it on any computer “on the same site”, but you may not give it away or sell it. If you have a legal copy we will provide some support and allow you with as many upgrades as you provide tapes for (or wish to retrieve with `ftp').

SM is provided ‘as is’ with no warranty, and we are not responsible for any losses resulting from its use.

In addition to this manual there is a tutorial introduction which you might find less intimidating. See section “The SM Tutorial” in *The SM Tutorial*.

This should be unimportant, but in case it isn’t you can submit SM bug reports (or requests for new features) using the URL `http://www.astro.princeton.edu/cgi-bin/gnatsweb.pl'; you want to query on category `sm' (and maybe `smdoc') from advanced query; note that you can save this query, set a bookmark, and so forth.
2 Description of SM

SM is an interactive plotting programme with a flexible command language. The plot data may be defined to SM in a number of ways. There is also a powerful mechanism for defining and editing plot ‘macros’ (sets of SM plot commands that are defined and invoked as plot “subprogrammes”).

The features of SM are described fully in the next few sections, but let us start with a description of how to produce your first SM plot. Before you start, notice that SM is case sensitive. Keywords may be typed in lower or uppercase (as we do in this manual), but we would recommend using lowercase. It is in fact possible to change the meanings of lowercase keywords, but this can be confusing. If you are interested, see the section on “overloading”. See ‘uppercase’ in the index if you really want to use your shift key.
3 A simple plot

Let us assume that you have a file called mydata, which looks like this:

This is an example file

1 1 1
2 4 8
3 9 27
4 16 64
5 25 125
6 36 216
7 49 343
8 64 512

SM has a history mechanism, so first type DELETE 0 10000 to tell SM to forget any commands that it has remembered. Then choose a device to plot on. You do this with a command like dev tek4010. If you don’t know what to call your terminal, use the LIST DEVICE command, ask some local expert, look at the description of DEVICE, or (if desperate) read the manual (see (undefined) [Graphcap], page (undefined)). You’ll know that you have succeeded if typing BOX draws a box.

You should now have successfully chosen a graphics terminal. To actually plot something, use the following set of commands. The text after the # is a comment, you don’t have to type this (or the #).

DATA mydata # Specify desired datafile
LINES 3 100 # Choose which lines to use
READ i 1 # Read column 1 into ‘i’
READ { ii 2 iii 3 } # Read column 2 into ‘ii’ and 3 into ‘iii’
LIMITS i ii # Choose limits, based on i and ii
BOX # Draw the axes
PTYPE 4 0 # Choose square point markers
POINTS i ii # Plot i against ii
CONNECT i ii # and connect the points
XLABEL This is i # Label the X-axis
YLABEL This is ii # And the Y

You should now have a graph. If you had wanted to plot the third column instead of the second you could have typed LIMITS i iii POINTS i iii instead. And of course you could plot ii against iii as a third alternative. You were not limited to only use squares as markers or solid lines to connect them - see PTYPE and LTYPE for details.

If you want a logarithmic plot, SM makes that easy for you. You can take logs of a vector using the LG (or LN) commands on vectors; try it - SET x=1,10 SET y=x**3 set ly=LG(y) LIMITS x ly CON x ly box. You might have wanted the axes to reflect the fact that you had logged the y axis. The TICKSIZE command allows you to do this, and this is in fact the commonest use of it. Try TICKSIZE 0 0 -1 0, and then repeating the x-y plot.
What if you want hard copy of your hard-earned graph? There is a command (actually a macro) called **playback** which will repeat all the commands that you have typed. Type **ERASE** to clear the screen, then **HISTORY** to see the commands that you have issued. You probably don’t want the **ERASE** command to be repeated, so type **DELETE** to delete it.\(^1\)

If there are any other mistakes use **DELETE m n** to delete the lines m to n containing them. Now type **playback** and your plot should reappear. But we wanted a hardcopy, so type **dev laser lqueue** (or whatever your friendly Guru recommends as a hardcopy device), then **playback**. This time, those plotting commands will appear on the laser printer not your terminal. To make them actually appear, type **hardcopy** or issue another **dev** command. Be sure to say **dev tek4010** (or whatever device you chose) before you read any more of this document. It is possible to edit the playback buffer, rather than simply deleting lines from within it. The section on ‘examples’ describes how to do this.

In fact, the same plot could have been produced from a data file which just contained the first column. After saying **READ i 1**, you could have said **SET ii = i*i SET iii = i**\(^3\)** and proceeded from there, or even skipped the file altogether by saying **set i = 1,8** instead of **READing** it at all. Such possibilities, and a good deal more, are described in greater detail in the rest of this manual.

What we just did was to define a simple ‘macro’, in this case the special one called **all** which **playback** manipulates. A more explicit use of a macro would be to define a macro to square a vector, that is to square each element of a vector. To do this say\(^2\)

```
MACRO square 2 { SET $1 = $2*$2 }
```

So to calculate the vector **ii** we could now say

```
square ii i
```

which is the same as saying

```
SET ii = i*i
```

So now that you have met macros, how do you save them? The simplest and least reliable way is to use SM’s history, and hope that the next time that you use SM it remembers the **MACRO** command that you used to define **square**, so you can re-issue it. (Try exiting SM, then starting it up again and typing **HISTORY**, then `\(^`nnn where **nnn** is the number which is next to the desired command in the resulting list.)

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\(^1\) There is a macro **era** defined as **DELETE HISTORY ERASE** that wouldn’t have appeared on the list in the first place, similarly **lis** is like **HISTORY** but won’t appear on the list of commands. As an alternative, you can use the macro **set overload** to make lowercase **erase** the same as **DELETE HISTORY erase**, along with a number of other changes. This could be confusing for neophytes!

See “overloading”

\(^2\) It is usually easier to use SM’s editor to create macros, try **ed square** or read on.
A brute force way is to say SAVE filename which will save almost all of your SM environment, to be recovered using the RESTORE filename command at some later time, or later SM session. Specifically, SAVE will save all your macros, variables, and vectors, along with your history buffer. This is a very convenient way in practice but it does mean that you tend to carry around lots of long-forgotten macros, variables, and vectors.

Another way is to write the macros to a disk file, using the MACRO WRITE command (see ‘Macros’). Then you can retrieve your macros with MACRO READ. You should note that your macro all will simply be a macro - to put it onto the history list say DELETE 0 10000 WRITE HISTORY all. (Of course, you could write a macro to do this for you). Maybe saving your playback buffer is something better done with SAVE, which will restore your playback buffer, while preparing files of useful macros is a use for MACRO READ. Once the idea of macros gets into your blood, you can of course use an editor to create your own files of macros, to be read with MACRO READ.
4 Facilities within the Command Interpreter

This is a guide to the use of SM variables, the macro processor, the help command, and the history facilities. The vector arithmetic and plotting facilities are described below. Various examples are scattered throughout the text, to give some guidance on the use of SM’s capabilities.

Perhaps the most important thing to know is how to escape from SM. If you have a prompt, simply type QUIT¹. If you are running some command, try CONTROL-C to get a prompt. Most commands will eventually return control to the keyboard following a CONTROL-C. In addition, the parser is reset, and the input buffer cleared. Sometimes CONTROL-C leaves a } on the buffer if it thinks that it’ll help get back to the prompt, which can generate an irrelevant syntax error. Occasionally it can still be confused – try typing a few characters and maybe a }.

When you have interrupted SM with a CONTROL-C, a macro called error_handler is executed, if it is defined. The one that we provide does things like setting the expansion back to 1, and resetting any window commands that you might have issued, and then prints a message handler... to tell you that it’s done its work. If you don’t like this, see ‘private initialisation’ in the index for how to get your own handler loaded automatically.

If you make a mistake, and SM notices a syntax error, it’ll print a message indicating where you were and which macro you were running. It is possible for the wrong macro to be reported (if SM has finished reading the macro before detecting the error), in which case you’ll be told that the error occurred in a macro that called the offender. Setting VERBOSE (see (undefined) [Verbose], page (undefined)) to 3 or 4 provides a more direct way of finding the true location of the error.

If you define the variable traceback to be 1 (maybe with the line traceback 1 in your ‘.sm’ file) you’ll get a traceback of what macros were active when the error occurred; the same caveats about the wrong macro being reported apply. In addition, the usual interrupt capabilities of your operating system will work under SM, with a couple of quirks.

Under Unix, in case of emergency, type CONTROL-\, and SM will ask you if you want to return to the prompt, and if you don’t it’ll offer a core dump, and then exit. As usual, typing CONTROL-Z (from the C-shell) will interrupt the process, which may be restarted later. Under VMS, CONTROL-Z will interrupt SM, and return you to the command interpreter (DCL). Typing CONTINUE will then allow you to restart SM².

¹ or q which is a macro defined as DELETE HISTORY QUIT. This will exit SM just the same, but the quit won’t appear on your history list, waiting to be playback accidently. Actually, q will query you before quitting
² If you are using VMS, you may prefer to use CONTROL-Y as your interrupt character. A suitable set of key definitions is in a file called maps_vms.dat in the top SM directory. It may be read with the READ EDIT command (see (undefined) [Key Bindings], page (undefined)), and this may be done automatically in your startup macro by the variable edit in your ‘.sm’ file.
If SM is running in a SPAWNed sub-process, then CONTROL-Z will reATTACH you to its parent. To continue SM, use the DCL ATTACH command. We strongly suggest that you learn how to do this, it makes life much easier – all you have to do is SPAWN a process from DCL and start SM from there. Do check with your VMS system manager to ensure that you have the right quotas for SPAWNing (Process limit must be at least 3, because SM will use one for itself and one for hardcopies). An especially simple way to do all this is to use the command file `kept_SM.com’ in the main SM directory. It’ll handle the spawning and attaching for you.

Another fact to bear in mind is that the characters ^, $, and # are special, as ^ is used by the history system, $ introduces a variable, and # starts a comment. The special meanings of all of these characters except ^ can be turned off by preceding them with a \. To type a ^, use the quote_next character (initially CONTROL-Q or ESC-q) to quote the ^; i.e. type ESC-q. A \n is interpreted as a carriage return, and a \ as the last character on a line escapes the newline, so that the line and the one following it are treated as one long line. A \ preceding any other character (except a “; see next paragraph) is simply a \. This character is used to set font types in the LABEL commands, so it has no special meaning to the command interpreter, which simplifies the entering of strings for LABEL commands.

A further problem is that symbols such as +, - , *, and / are used to separate words, which is what you want for mathematics, but maybe not what you had in mind for filenames. Enclosing a word in double quotes turns off all special meanings except ^; an embedded " may be escaped with a \. Single quotes are used quite differently; enclosing a word in 'single quotes’ makes it into a string so '12’ is a two-character string and not an integer at all. There are times when this is important; for example if(y == 'yes’) tests if the vector y is equal to the string ‘yes’, whereas if('yes' == 'yes’) asks whether two identical strings are equal (they are). When you remember that I can legally say set yes='no’ you’ll appreciate the distinction.

The characters { } also perform quoting, turning off the special meanings of all characters (including single and double quotes, but not ^). The difference between double quotes and braces is that the latter have grammatical value; they are part of the syntax that SM understands. In most cases you can use angle brackets instead of curly ones if the grammar needs the brackets but you don’t want to turn off expansions (see (undefined) [Variables], page (undefined)).

SM is case-sensitive. It will accept keywords in either upper or lower case, but this is a special dispensation on its part. If you insist on typing in uppercase say load uppercase when you first start SM, or put the line uppercase 1 in your ‘.sm’ file. Furthermore keywords may not be abbreviated. This is not a great hardship as it is easy to define macros which make the minimum abbreviation a synonym for the full command. Many such macros are predefined for you when you first use SM; see (undefined) [Libraries], page (undefined) for details. In particular, certain common abbreviations of commands have been predefined by the SM startup file.

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3 In fact you can rebind any character to replace ^, see (undefined) [History Editor], page (undefined)
Every time that SM is started, it looks for an environment file called `.sm' which consists of names of variables and their values. From # to the end of a line is taken to be a comment. A list of directories to be searched in order for `.sm' files is compiled into SM, it usually consists of the current directory, then your home directory, and then some system directory. The system default can be over-ridden by defining the environment variable `SMPATH' which is a list of directories separated by single spaces. Each directory on the search path is tried in turn until a file is found containing the desired variable, which allows your choices to take preference over those of the system administrator. In the list of directories . is taken to be the current directory, and ~ is your home directory unless you specified a command line `-u name' option, in which case it is taken to be name's home directory instead. This means that `sm -u name' will usually run SM as if you were name. If name is null, then SM won't look for a `.sm' file in anyones home directory. The default path is equivalent to an `SMPATH' of

``export SMPATH=". ~ /u/sm/lib/"
''

(or an equivalent incantation). Note that the directory `/u/sm/lib/' ends in a / so that a filename can be directly appended (on a VMS system it would probably end in a : or ]).

An example file would be (the filenames are written in Unix)

``# I'm a comment line
fonts /users/sm/fonts.bin
graphcap /users/sm/graphcap
help /users/sm/help/
macro /users/sm/macros/
name Robert # Or alternatively 'Dr._Lupton'
''

The fonts file contains the SM fonts (in a binary form), the graphcap entry is used to define the file used to describe graphics terminals (see [Graphcap], page [undefined]), help is the directory used by the help command, macro is the default directory where macros reside, and name is what SM will call you (you can put spaces into your name by using underscores, e.g. My_Lord will be referred to as My Lord). You can access entries in the environment file yourself, as described in the section on variables. See the section [Libraries], page [undefined] to see how entries in the `.sm' file are used to influence the behaviour of SM, or consult your local expert. You might want to borrow someones `.sm' file when you first use SM, although you should do fine without one. For more detail, and further special entries, see [Environment Variables], page [undefined]. The name of the `.sm' file can be specified on the command line as "-f name" or you can ask to use name's .sm file with `-u name'. VMS users should ensure that SM has been installed as a foreign command to take advantage of these capabilities.

SM then tries to read in any macros in the file `default' in the directory `macro' and attempts to execute the macro `startup' if it exists. If `-m filename' appears on the command line, this is taken to be the name of another file of macros and these are read, and the eponymous macro is executed (after any pre- or suf- fix has been removed. For instance if you start SM with the
command \texttt{sm -m /home/tst.m}, it will first read the file \texttt{/home/tst.m}, and then attempt to execute the macro \texttt{tst}).

Anything left on the command line is treated as if it had been typed at the prompt, for example \texttt{sm restore vital.save} will start by \texttt{RESTOR}ing from the file \texttt{vital.save} (see \texttt{RESTORE} if you want to know what this means). The \texttt{-m} option is not really a good way to personalise \texttt{SM}. The \texttt{startup} macro discussed under ‘useful macros’, which is run every time that you start \texttt{SM}, looks for a directory \texttt{macro2} in your ‘\texttt{.sm}’ file, and if it is there reads a file ‘\texttt{default}’ from it, and executes the macro \texttt{startup2} which it expects to find there. On case-insensitive operating systems, such as VMS, you may need to quote the command line to prevent it being translated to upper case. \texttt{SM} then attempts to read a set of history commands from a file in the current working directory, passes control to the input routine and issues a prompt. The file is given by the entry \texttt{hist_file} in your ‘\texttt{.sm}’ file, and if it isn’t present then no history will be remembered.

You are then able to type commands, as many as will fit on one line\textsuperscript{5}, and use the features described below.

You can use a combination of these features to run \texttt{SM} in ‘batch’ mode. If you had a history file that you just wanted to run, then you could start \texttt{SM}, say \texttt{playback}, and quit. You could have a macro called \texttt{batch} in \texttt{batch.m} that did just that, and say \texttt{sm -m batch.m} to execute it. In fact, you don’t even need your own macro as one is pre-defined for you so \texttt{sm batch} is sufficient. You could write your own macros along this lines to do more complex tasks. A more convenient alternative (under unix) would be \texttt{sm -S < history_file} where the \texttt{-S} is explained in the next paragraph.

For completeness, we should mention the other command line flags, \texttt{-h}, \texttt{-l logfile}, \texttt{-n}, \texttt{-q}, \texttt{-s}, \texttt{-S}, \texttt{-v\#}, and \texttt{-V}. The \texttt{-h} prints a summary of command line options, if you specify a logfile with \texttt{-l} everything that you type at the keyboard is copied into the logfile (except editing commands). When you start \texttt{SM} it usually runs a macro \texttt{startup}; \texttt{-n} prevents this. The \texttt{-s} (for ‘stupid’, or ‘silent’ or ‘suppress’) flag disables the command line editor (although the history list is still saved, so commands like \texttt{playback} will work), \texttt{-q} suppresses the initial ‘Hello’ message, and \texttt{-S} is like \texttt{-s} but it also suppresses the prompt and stops \texttt{SM} from intercepting \texttt{CONTROL-C}. You can get the same effect as \texttt{-s} from inside \texttt{SM} with the command \texttt{TERMTYPE none}. If you are reading from a file or pipe \texttt{SM} behaves as if you had invoked it with the \texttt{-S} flag. This is useful if \texttt{SM} is being run from inside another programme, via a pipe (VMS: mailbox), or on a very stupid terminal. If you want to set a particular value of verbose, use \texttt{-v} for example \texttt{-v-3} is equivalent to the \texttt{VERBOSE -3}

\textsuperscript{4} Under VMS, \texttt{SM} must have been installed as a foreign command for this to work, and it must not have been linked with the debugger

\textsuperscript{5} Occasionally a \texttt{<CR>} is required by \texttt{SM}, so putting two commands on one line will give a syntax error. The cause is the way that the grammar is written (see \texttt{(undefined)} [Command Internals], page \texttt{(undefined)}), the fix is either to use two lines, or else to put an explicit carriage return at the appropriate point with a \texttt{\textbackslash n}
command given interactively. If you want to know SM’s version string without starting SM, you can use the –V flag.
5 String Variables

Some SM users seem to be confused by variables and vectors; if you are one of these, the section on quoting (see (undefined) [Quoting], page (undefined)) might help.

SM maintains a set of variables which are defined with one of the statements

\[ \text{DEFINE name value} \]
or\[ \text{DEFINE name \{ value_list \}} \]
or\[ \text{DEFINE name ( expression )} \]

where name must consist of digits, letters and `.' (but must not start with a digit), and may be a keyword.

Value may be a word or a number. Value_list has no such restrictions and may contain many words. Note that due to the presence of the \{\}, variables are not expanded (i.e. replaced by their value) in value_list, whereas they are in value. In fact, the list can be delimited by <> rather than \{\}; see DEFINE for details.

The expression in DEFINE variable ( expr ) should be a scalar; if it is not, the first element of the vector will be used and you will be warned, if VERBOSE (see (undefined) [Verbose], page (undefined)) is one or greater. Sometimes you just want to evaluate an expression and treat the answer as a string; in this case use the special vector form \$(expr) which is replaced by the value of the expression — for example echo e is \$(exp(1)). Expressions are further discussed under ‘Vectors and Arithmetic’.

There are a number of special variables whose value is always the current value of some internal SM variable such as the current position or the point type. The variable “date” is also special and expands to give the current time and date, — try typing echo $date. You can freeze these variables at their current value by saying define name | (see below).

Each time SM reads $name it replaces it by its value, considered as a character string. For example,

\[ \text{DEFINE hi hello} \]
\[ \text{WRITE STANDARD $hi} \]

will print hello. This expansion is done before even the lowest level of lex analysis, so if a command is attempting to read a value it is possible to give it the name of a SM variable. An example would be the XLABEL command, which writes a string as the x-axis label of a graph,

\[ \text{DEFINE name Aelfred} \]
\[ \text{XLABEL My name is $name} \]
will invoke the XLABEL command, and write My name is Aelfred below the x-axis. (Incidentally, DEFINE Aelfred Aethelstan YLABEL $$name will write Aethelstan as the y-axis label, which can be handy in macros. The use of the double $$ indicates to SM to do a double translation, as it first expands to $Aelfred which then expands to Aethelstan).

A variable can be deleted by DEFINE name DELETE so for example the macro

MACRO undef 1 { DEFINE $1 DELETE }

invoked as

undef name

will undefine the variable name (see the section on macros if you are confused).

There are also three special values, :, |, and ?. The command define name : means ‘get the value of name from the environment file’. If this fails, and if the variable is all uppercase, SM will then try to use the value of an environment (VMS: logical) variable of the same name. Using define name ? means ‘read the value of name from the keyboard’. You can specify a prompt to be used, see DEFINE for details. The form with | has changed a little with version 2.1.1. The variables that you can use with | have not changed, but their usage has slightly. They are all defined for you when SM starts and each is always correct, tracking the current value of the corresponding internal variable. For example, try echo $angle angle 45 echo $angle. If you now say define angle |, $angle will cease to track the internal value and will remain fixed (the same effect can be achieved with define angle 45). When you say define angle delete it will once more track the internal value. Your old code will continue to work, but in many cases it is possible to remove the explicit definition with |. This special sort of variable will not be SAVED, and will not show up if you list the currently defined variables. A list of the | variables is given in the section on DEFINE.

So using the example `.sm’ environment file listed in the previous section of the manual, DEFINE name : will define name to be Robert, DEFINE angle | will give the last value set by the ANGLE command, and DEFINE datafile ? will ask you for the value of ‘datafile’, which can be useful in macros. For example,

DEFINE noise ? { Ring bell? } IF(’$noise’ != ‘n’) { bell }

will execute the macro bell if you type anything but n in reply to the question ‘Ring bell?’.

When writing macros, it is also sometimes useful to know if a variable has been defined. The variable $?name has the value 1 if name is defined, otherwise it is 0. For instance, there is a line

define term : if($?term) {术语 $term }

in the startup file, to set a termtype if present in the environment file.

There are also commands to read the values of variables from data files defined with the DATA command.
DEFINE name READ i  
   or  
DEFINE name READ i j

will set name to be the i'th line of the file (or the j'th word of the i'th line). An example is given in the section on `useful macros'. You can read variables from the headers of binary files (specified with the IMAGE command) using DEFINE name IMAGE, although this is only supported for a limited class of file_type's (see {undefined} [2-D Graphics], page {undefined}).

All currently defined variables may be listed with

   LIST DEFINE [ begin end ]

where the optional begin and end define the range of variables (alphabetically) to be listed. You might prefer to use the macro lsv which won’t appear on your history list.

Variables are usually not expanded within double quotes or { }. If for some reason you need to force expansion within double quotes, it can be done with $!name. The macro ‘load’ discussed under useful macros gives an example of this mechanism. If you need to expand a variable, with no questions asked (and even within { }), use $!!name.

Sometimes you may want to terminate a variable name where SM doesn’t want to, and this can be done with a trick involving double quotes. Say you are writing a macro to find all the stars redder than B-V = 1.0 in a set of data vectors, and you want to rename them with a trailing “_red”, so star goes to star_red. So you write a foreach loop,

   FOREACH x ( U B V R I J K ) { SET $x_red = $x IF(B-V >1)}

Well, that won’t work because SM thinks that you are referring to a previously defined variable named x_red, so it will complain that x_red is not defined. But if you write it as $x"_red the " separate the x from the _red until $x is expanded, and then disappear, and all is well. When a variable is read, SM skips over all whitespace before the definition, and this can cause problems if you hit CONTROL-C in the middle, as the rest of the command will be thrown away. If you ever hit a CONTROL-C, and can’t get a prompt, try typing any non-whitespace character.

Variables are string-variables, and are not primarily designed for doing arithmetic (that’s what vectors are for). This is a common source of confusion so let’s consider some examples (at the risk of anticipating some later sections of the manual).

   DEFINE a 12

defines a variable a which consists of the two characters ‘1’ and ‘2’, and which can be used anywhere — for example xlabel $a. What about vectors? Consider

   SET x=10

which defines a single-element vector whose value is ten, ready to be used in expressions such as
SET y=$a + x*12

Note that the $a is still just the two characters ‘1’ and ‘0’, but in this context that is interpreted as the number ten. So what does

DEFINE y $a+x*12

do? Well, actually it results in a syntax error (the ‘+’ ends a word), so try

DEFINE y <$a+x*12>

This defines the variable y as the string ‘10+x*12’, it doesn’t evaluate the expression. You can evaluate the expression if you want with

DEFINE y ( $a+x*12 )

which defines y as the string ‘130’. Incidentally, you can sometimes get away without an explicit variable with the syntax $($a+x*12) which also expands to the string ‘130’.

The fact that variables are simply strings can be used to build complex commands; consider for example the macro

readem             # read multiple lines columns with names in row 1
    READ ROW names 1.s
    DEFINE rc <$names[(0)]> 1>
    DO i=2,DIMEN(names) {
        DEFINE rc <$rc $(names[($i - 1)]) $i>
    }
    LINES 2 0
    READ < $rc >

which reads the names of a set of columns from line 1, builds a command to read the data in the variable rc, and then reads all the data in one command. You could of course loop through names reading each column in turn, but this should be a good deal faster.

By default variables are global, so if you have a variable $i, and a macro that you call also uses a variable $i, the macro will change the value that you so carefully defined. To avoid this, it is possible to force variables (and also vectors) to be local, using a command like DEFINE i LOCAL; in this case the variable $i will softly and suddenly disappear when you leave the current macro (and therefore you cannot make variables local at the topmost level, i.e. at the command prompt). In fact, such variables aren’t strictly local, they have what’s called nested scope, as they are visible from any macros that you may call — they simply do not propagate backwards up the call stack. You are free to make a variable local in any (or all) macros, there’s no restriction on how deep such local declarations may be nested.
6 Command History

It is often very useful to be able to repeat a command, or perhaps correct a mistake in what you have just typed. Ways of doing this are usually referred to as ‘history’, and SM has two distinct mechanisms. One is very similar to that of the Unix C-Shell, and the other allows you to edit commands using a syntax similar to the popular editor ‘emacs’, or a generalisation of the DCL history under VMS. If you are not familiar with Unix, emacs, or VMS don’t despair; a description of the commands and how to invoke them follows in this document. Both of these mechanisms are implemented by the routine which reads input lines. As each line is sent to the parser, it is copied onto a history list. This list may be printed with HISTORY, and the commands may be re-used by referring to them by number, as \(^nn\), or by a unique abbreviation, as \(^abbrev\). In addition, the last command may be repeated by using \(^\) and the last word of the last command by \(^\$\).^1 These symbols are expanded as soon as they are recognised (see examples, or experiment), and are then available for modification by the editor. Sometimes a \(^string\) will retrieve a command beginning \(string\), but not the one that you want. Version 2.1.1 no longer supports the use of \(^TAB\) to search for the next-most-recent command beginning \(string\), but you can use the search commands (\(CONTROL-R\) and \(CONTROL-S\)) instead. Some people really don’t want \(^\) to be their history character, either because they’re used to something else (such as !), or because they want to type lots of real \(^\)s (e.g. you are using \(Tk\)-style strings); if this describes you, rebind them – see the next section. If you are considering the history list as a sort of programme to be repeated you may think that HISTORY lists the commands in the wrong order; if so use HISTORY -. For example, if I type:

```
   PROMPT @
   echo I like SM
   HISTORY
```

SM will set the prompt to be @, replace the macro echo by its value WRITE STANDARD and print

```
   I like SM
```

and then

```
   3 HISTORY
   2 echo I like SM
   1 PROMPT @
```

(The actual numbers will be different, depending on what other commands you have executed, and also because SM may have read a history file. In that case there’ll be many more commands on the list, but no matter.) If I then type

```
   2 <CR>
```

^1 \(^\) and \(^\$\) really do get back the last command typed, even if it isn’t on the history list. If you want the last remembered command, use up-arrow or \(^P\)
(that is `2 not control-2) the screen will look like

```bash
@ echo I like SM
I like SM
```
as if I had just typed it in (@ is the prompt). Typing

`^-` (Yes, ^$ ) <CR>

will now result in SM printing (truthfully)

```bash
I like SM (Yes, SM )
```

It is possible to delete commands from the history buffer with the **DELETE** command. If the command is given with zero, one, or two arguments, then the specified range is deleted (but their numbers are not re-used). If no arguments are given, the last command on the buffer is deleted, and its number is released to be re-used. In other words, the command **DELETE** will delete first itself, and then the previous command from the history list. The command **DELETE HISTORY** only removes itself from the history list, and several of the common commands are defined as macros which use it, for instance `dev` is defined as **DELETE HISTORY DEVICE**. This means that the command will not appear on the history list, to confuse you when you do a playback. But if you now innocently use `dev` in a macro, that macro won’t appear on the list either. Still worse, if you use `dev` twice in one macro, the previous command will be deleted as well which could be quite confusing. You can also delete lines of history using **ESC-CONTROL-D** as described shortly.

The numbering is consecutive, starting at zero. Each command retains its number until you use a **HISTORY** command to list the remembered commands, in which case they are all renumbered, and it is these new numbers that are listed.

By default only 80 lines are remembered, and as you continue typing earlier ones fall off the list.

Because the history buffer is also used to compose complex commands, this limit can be aggravating. You may be able to defeat this by putting many commands on each line (you may have to use \n to terminate label commands explicitly) or by writing macros. Alternatively you can define a longer history buffer when you start SM by including an entry **history** in your environment file

which gives the number of commands to be remembered. If you set **history** to be 0 the history list is made infinitely long. Incidentally, it is the total number of commands that matters, not the range of history numbers present.

This limit on the number of history lines isn’t enforced while writing a macro onto the history list (using **WRITE HISTORY**). You can use this fact to write a sneaky macro that extends your history; type **HELP extend_history** if you are interested.

Some people seem to like their history editors to remember where they were, so that after they retrieve and execute a command the next **CONTROL-P** or ↑ will retrieve the command one further
back on the history list (that is, if you have just retrieved command number 123 and executed it as command number 234, then CONTROL-P will get you command number 124; you can execute it as command number 235). If this describes you, define the variable remember_history_line, which you can either do directly, or by putting a line remember_history_line 1 in your ‘.sm’ file.

The editor allows you to modify commands, either as you type them or as you retrieve them from the history list. The various editing commands may be bound to keys of your choosing, but the default bindings are given in this list of possible commands:

CONTROL-A
  Go to start of line.

CONTROL-B
  Go back one character. (Equivalent to ← ).

CONTROL-C
  Interrupt (as usual).

CONTROL-D
  Delete character under cursor.

CONTROL-E
  Go to end of line.

CONTROL-F
  Go forward one character. (Equivalent to → ).

CONTROL-H
  Identical to CONTROL-% (DEL). Delete character to left of cursor.

CONTROL-I (TAB)
  Insert spaces up to the next tab stop. By default a tab is taken to be 8 characters wide, but this may be changed by specifying tabsize in your ‘.sm’ file.

CONTROL-J (LF)
  Equivalent to CONTROL-M.

CONTROL-K
  Delete to end of line. The deleted string is stored, and may be restored using CONTROL-Y, repeatedly if so desired.

CONTROL-L
  Redraw the current line.

CONTROL-M (CR)
  Send line to be executed. Some terminals seem to replace CONTROL-M with a linefeed (CONTROL-J), thereby making it impossible to make SM obey you. We therefore make CONTROL-@ equivalent to CONTROL-M for emergency use. (This is control-space on many terminals).
CONTROL-N
Get the next command on the history list, if it exists (see CONTROL-P). (Equivalent to ↓).

CONTROL-O
Execute the previous command on the history list. Equivalent to CONTROL-PCONTROL-ECONTROL-M.

CONTROL-P
Get the previous command on the history list, if it exists (see CONTROL-N). (Equivalent to ↑).

CONTROL-Q
Quote next character; Turn off any special significance to the editor. CONTROL-Q is often used by the terminal, so we have defined CONTROL-[q (that is escape followed by q) as an alternative.

CONTROL-R
Search backwards (reversed) for a string; the opposite of CONTROL-S. The ‘string’ can actually be any regular expression (see the manual entry for APROPOS). If you specify a zero-length string (i.e. simply hit carriage return) the previous search string will be reused.

CONTROL-S
Search forward for a string; the opposite of CONTROL-R. CONTROL-S is often used by the terminal, so we have defined CONTROL-[s (that is escape followed by s) as an alternative.

CONTROL-T
Toggle insert/overwrite. By default, characters are inserted before the cursor. If overwrite is set, they replace the character under the cursor. Note that ESC-u will not correctly restore words deleted with ESC-d in overwrite mode.

CONTROL-U
Delete from the cursor to the start of the line.

CONTROL-V
Go forward 5 lines.

CONTROL-W
Delete the previous word. Identical to ESC-h

CONTROL-Y
Insert the string most recently deleted with CONTROL-K after the cursor.

CONTROL-Z
Return to the operating system, without killing SM. (Under VMS, if you are running SM in a spawned subprocess CONTROL-Z will attach you to DCL. Otherwise, SM returns you to DCL.)

CONTROL-? (DEL)
Equivalent to CONTROL-H.
ESC-CONTROL-D
Delete this line and remove it from the history list. Note that this is different from just clearing a line with (e.g.) CONTROL-U, which only erases a copy of the line.

ESC-< Go to the first line of a macro, or the oldest history command.
ESC-> Go to the last line of a macro, or the most recent history command.
ESC-g Go to a given line of a macro, or a given history command. You’ll be prompted for the line number, if you change your mind you can get out with DEL or CONTROL-H.
ESC-q Quote the next character, turning off any special significance to the editor. Identical to CONTROL-Q.
ESC-s Search forward for a string. Identical to CONTROL-S.
ESC-v The opposite of CONTROL-V, go back 5 lines.
ESC-y Like CONTROL-Y, except that it gets older deletions, cycling back through a collection of (currently 5) deleted lines.

Some ESC-letter combinations are available which operate upon complete words. A word is defined as a whitespace delimited string, so 2.998e8 is a perfectly good word. In addition, it is possible to undelete words that have been deleted with an ESC-d or ESC-h.

ESC-b Go to the start of the previous word.
ESC-d Delete to the beginning of the next word.
ESC-f Go to the beginning of the next word.
ESC-h Delete back to the beginning of the current word. The same as CONTROL-W.
ESC-u Restore the last word deleted, putting it before the cursor. Further ESC-u’s will restore more words. When no more are available, the bell is rung.

Any printing character is inserted before the cursor (unless overwrite has been set with CONTROL-T ). Illegal characters ring the terminal bell. If you insert a non-printing character on a line, the cursor may get confused.

If ever you are stuck at the command interpreter, and you want to send a signal to the operating system (e.g. a CONTROL-Y to DCL), but SM is catching the key and using it for its own purposes, the easiest thing to do is to define a macro such as MACRO aa {aa} , and then run it. While it is running (i.e. until you type CONTROL-C) keys should have their usual functions.
7 Changing Key-Bindings

As mentioned above, it is possible to redefine the meanings of keys to the history (and macro) editor. The command `EDIT keyword key-sequence` will make typing that sequence of keys correspond to the command `keyword`. For example, to make `CONTROL-R` redraw the current line, you could say `EDIT refresh CONTROL-R`. The keyword can be any in the list below, or any single character. Each character in the key-sequence can be a single character, `CONTROL-C`, or `\nnn` where `nnn` is an octal number. Alternatively, `READ EDIT filename` will read a file specifying the new bindings which has two lines of header, followed by pairs of `keyword key-sequence`. Lines starting with a `#` are comments. An example is the file for VMS users given below.

A problem can come up with multiple-key sequences. Imagine that you have bound some function to `CONTROL-XCONTROL-A`, for example

```
EDIT end_of_line `X`A
```

then what happens when you try it? SM sees the `CONTROL-X` and uses its default binding, `exit_editor`, and then sees a `CONTROL-A` and goes to the start of the line, which wasn't the desired effect. The solution is to tell SM that `CONTROL-X` is not a legal key, in which case it will either ring the terminal bell (if there are no key-sequences starting with an `CONTROL-X`), or wait for the next key. In short,

```
EDIT illegal `X
EDIT end_of_line `X`A
```

should work.

On a somewhat similar topic, the `KEY` (see `undefined` [Key], page `undefined`) command may be used to define a key to generate a string. See the end of the section on macros for how this works.

All the current key definitions may be listed using `LIST EDIT`, including the `KEY` definitions. The names of operators, and their default bindings, are given in the following table:

<table>
<thead>
<tr>
<th>Operator</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>CONTROL-A</code></td>
<td>start_of_line</td>
</tr>
<tr>
<td><code>CONTROL-B</code></td>
<td>previous_char</td>
</tr>
<tr>
<td><code>CONTROL-C</code></td>
<td>delete_char</td>
</tr>
<tr>
<td><code>CONTROL-E</code></td>
<td>end_of_line</td>
</tr>
<tr>
<td><code>CONTROL-F</code></td>
<td>next_char</td>
</tr>
</tbody>
</table>
CONTROL-G
   illegal
CONTROL-H, DEL
   delete_previous_char
CONTROL-I
   tab
CONTROL-J
   carriage_return
CONTROL-K
   kill_to_end
CONTROL-L
   refresh
CONTROL-M, CONTROL-@
   carriage_return
CONTROL-N
   next_line
CONTROL-O
   insert_line_above
CONTROL-P
   previous_line
CONTROL-Q, ESC-q
   quote_next
CONTROL-R
   search_reverse
CONTROL-S
   search_forward
CONTROL-T
   toggle_overwrite
CONTROL-U
   delete_to_start
CONTROL-V
   scroll_forward
CONTROL-W, ESC-h
   delete_previous_word
CONTROL-X
   exit_editor
CONTROL-Y
   yank_buffer
CONTROL-Z

    attach_to_shell

ESC-<    first_line
ESC->    last_line
\034    escape
ESC-b    previous_word
ESC-d    delete_next_word
ESC-f    next_word
ESC-g    goto_line
ESC-u    undelete_word
ESC-v    scroll_back
ESC-y    yank_buffer
ESC-CONTROL-D
    delete_from_history
~    history_char

A simple example of a bindings file for a hardened VMS user might be

# This is a set of DCL-ish key maps for SM
# name   key
  toggle_overwrite   ^A
  start_of_line     ^H
  delete_previous_word  ^J
  yank_buffer      ^R
  search_reverse   ^[r
  attach_to_shell  ^Y

Note that that’s the two characters ^ and A not control-A. It could just as well have been written \001. We need a new character for yank_buffer now that CONTROL-Y is otherwise engaged, and I have chosen CONTROL-R (which means that I can’t use CONTROL-R to search backwards, so I chose ESC-r for that). You should be warned that some terminal protocols map CONTROL-M to CONTROL-J, so this use of CONTROL-J could render you unable to issue commands. As mentioned above, in an emergency CONTROL-@ can be used instead of CONTROL-M.

When SM is started, or whenever the TERMTYPE command is used to change terminals, the arrow keys are bound to the commands previous_line, ext_line, previous_char, and ext_char. For terminals such as a Televideo-912, which uses characters such as CONTROL-K for arrow motion, these can supersede the previous meanings (in this case kill_to_end); The only fix is to use the EDIT or READ EDIT command to get what you want, probably within a macro.
If you want to use ’ as your history character instead of ^ you need to say `edit history_char ^`. If you try to use a character special to SM such as ! this won’t work (you’ll get a syntax error) and you’ll have to use the next alternative, namely put the commands into a file and say `read edit filename`, for example:

```
# Change the history character
# name  key
history_char  !
```

Because this particular change is so common, it’s possible to specify that ’ be your history character simply by including a line `history_char ’ in your `.sm` file (or you can choose your own character. Choosing 0 has the effect of using the default, ^).

SM needs to know something about the terminal that you are using, so as to run the history/macro editor. This is entirely separate from the problem of describing the terminal’s graphics. It will try to discover what sort of terminal you’re on by using the value of `term` from your `.sm` file, or failing that the value of the environment variable `TERM` (Unix) or the logical variable `TERM` (VMS). A `term` entry of `selanar -21` is equivalent to a `TERMTYPE selanar -21` command. You can also use the `TERMTYPE` command directly. SM then uses the terminal type specified to look up its properties in the `termcap` command database (see [Termcap], page [undefined]). You can also use `TERMTYPE` to specify the size of the screen, or to turn off SM’s idea of where the cursor is. On some terminals, you can only send a cursor to an absolute position and this is chosen to be the bottom of the screen. This is not what you want for, e.g., a VT240 as it will lead to your graph scrolling off the screen. The use of a negative screen size to `TERMTYPE` will disable this cursor motion, but will also make editing lines slower. If a line of your graph is being deleted when the SM prompt appears, you may need to use `TERMTYPE dumb` or `TERMTYPE none`. 
8 Talking to the Operating System

Any line from ! to the newline is passed to your shell (DCL under VMS, the Bourne shell under unix. If you set the variable SHELL in either your ‘.sm’ file or the environment it will be used instead; the former takes priority).\(^1\) For example, !ls or !directory will list the current directory. The return code from the command is available in the variable $exit_status, on unix systems it will be 0 for success, for weirder systems you should look in the system manual for the return value of the C function system. $exit_status is one of the variables that can be set with DEFINE exit_status |.

It is also possible to change the directory that SM uses to look for data or macro files with the CHDIR command - for instance CHDIR ".../more_data"\(^2\). If a directory name starts with ‘~’, CHDIR replaces the ‘~’ with your home directory. This is the only place that ‘~’ is treated specially, for instance it is not interpreted by the DATA command. Because directory names often contain mathematical characters such as [ or /, it is wise to quote the directory, or use the macro cd which quotes it for you.

---

\(^1\) The first of these commands in a SM session may be rather slow under VMS, as we have to spawn a subprocess.

\(^2\) Unfortunately, this is currently not available to VMS users.
9 Macros

In SM, it is possible to define sets of plot commands as “subprogrammes”, which can be used just like a plot command, to generate a standard plot. These plot macros allow variables (e.g. name of the data file, plot label or limits, etc) to be supplied at execution time.

You can also bind commands to keys to save typing; for example I usually bind ‘cursor’ to the PF1 key of my terminal. Such keyboard macros are discussed under KEY and at the bottom of this section.

The macro facility consists of commands to define macros, delete them, write them to disk files, read them from disk files, delete all those macros defined in a specified disk file and list all currently defined macros. In addition, the help command applied to a macro prints out its definition. It is possible to pass up to 9 arguments to a macro, referred to as $1, ... , $9, and in addition $0 gives the name of the macro. While macro arguments are being read they are treated as if they are in sets of {}, except that variables are expanded. If you want to include a space in an argument, enclose it in quotes. If the number of declared arguments is 10 or more, the macro is treated as having a variable number of arguments. If it is 100 or more the last argument extends to the end of the line. For further discussion see the discussion of how macros are used.

A macro is defined by the statement

MACRO name nargs { body-of-macro }

or

MACRO name nargs < body-of-macro >

where name may be up to 80 characters, and must not be a keyword, and body-of-macro is the statements within the macro, and may be up to 2000 characters long. Macros defined using an editor on a file may be up to 10000 characters long. If nargs, the number of arguments, is 0 it may be omitted. Macros may also be created using the MACRO EDIT command, which is discussed below, and which is probably easier. To define the macro in a disk file, the file format must be: the name of the macro starts in the first column, followed by a tab or spaces, followed by the number of arguments, if greater than 0, followed by commands, followed by comments if any. The next line and any necessary subsequent lines contain the macro definition (starting in a column other than the first one). Any number of macros may appear in the same file, as long as the macro name is given in the first column and the definition starts in some other column. The first two blanks or tabs are deleted in continuation lines, but any further indentation will survive into the macro definition. Tabs will be replaced by spaces as the macro is read. By default a tab is taken to be 8 characters wide, but this may be changed by specifying tabsize in your ‘.sm’ file.

When a macro is invoked, by typing its name wherever a command is valid, for example at a prompt, it first reads its arguments from the terminal (if they are not in the lookahead buffer,
it will prompt you for them), and defines them as the variables $1, \ldots, $9, before executing the commands contained within the macro. The number of arguments must be declared correctly.

As an alternative it is possible to declare that a macro has a variable number of arguments by declaring 10 or more\(^2\). The macro will then expect between 0 and the number declared modulo 10 arguments, all on the same line as the macro itself. (i.e. the argument list is terminated by a newline, which may either be a ‘real’ one, or an \(\n\)). If the number of arguments is 100 or more it is still reduced modulo 10, but the last argument is taken to be the rest of the line (which may consist of many words). The macro may find out if a particular argument is provided by using $? to see if the variable is defined. For example the macro check, in the format in which it would appear in a file,

```
check 11 if($?1 == 1) { echo Arg 1 is $1 }
```

will echo its argument, if it has one, and

```
split 102 if($?2 == 0) { DEFINE 2 "(none)" }
    echo $1:$2:
```

if invoked as `split word many arguments` will print `word:many arguments:`. If you add an explicit newline, `split word many\n arguments`, you’ll get `word:many:` and then a complaint that `arguments` is not a macro.

If you try to execute a non-existent macro, if it is defined SM will call a special macro called `macro_error_handler`. It has two arguments; the first is the string `NOT_FOUND`, and the second is the name of your non-existent macro. When you start SM, the error handler is:

```
macro_error_handler 2 ## handle errors associated with macros
    if($?missing_macro_continue) {
        echo $2 is not a macro
        RETURN
    }
    if('$1' == 'NOT_FOUND') {
        del1
        define 3 "$2 is not a macro; aborting"
    } else {
        define 3 "Unknown macro error for $2: $1"
    }
    USER ABORT $3
```

which causes an immediate syntax error (the `USER ABORT`), and remove the errant command from the history list (the `del1`). You can turn this off by defining the variable `$missing_macro_continue`, which you can do in your `.sm` file; this was the default in SM versions 2.1.0 and earlier, and is what you get if the macro `macro_error_handler` isn’t defined.

\(^2\) More accurately, by specifying two or more digits; see \(\text{undefined}\) [Macro], page \(\text{undefined}\) for more details and examples
Unfortunately we can get into trouble with IF’s at the end of macros, for much the same reason that RETURN can get into trouble (see (undefined) [Command Internals], page (undefined)). The symptoms are that a macro either gets the arguments that were passed to the macro that called it, or complains that it can’t handle numbered variables at all because it isn’t in a macro at all. To avoid this, there is an explicit \n at the end of the macro check. It is possible to redefine the values of arguments (it won’t affect the values you originally specified, arguments are passed by value), or to DEFINE values for arguments that you didn’t declare. The latter case allows you to have temporary variables, local in scope to the macro. An example is the rel macro, which is defined as

\[ \text{rel 2 DEFINE 1 ($1) DEFINE 2 ($2) RELOCATE $1 $2} \]

which allows you to specify expressions to the relocate command. For more examples see the ‘useful macros’ section.

Newlines are allowed within macros, and as usual any text from a # to the next newline is taken to be a comment. If a # is needed within a macro, escape the # with a \ or enclose it in double quotes. If a macro starts with a comment the comment will not affect the macro’s speed of execution. Macros starting with ## are treated specially by SAVE (they are not saved) and MACRO LIST (they are not listed if VERBOSE is 0).

If the macro command is given as

\[ \text{MACRO name \{ DELETE \}} \]

or

\[ \text{MACRO name DELETE} \]

the macro will be deleted (you can also delete a macro from the macro editor by specifying a negative number of arguments). If the name is already defined, it will be silently redefined. Macros may be nested freely, and even called recursively. For example, the definition

\[ \text{MACRO aa \{aa\}} \]

is perfectly legal, but SM will go away and think about it for ever if you ever type aa (or at least until you type CONTROL-C.) The definition

\[ \text{MACRO zz \{ zz zz \# comment: not recommended \}} \]

is also legal, but in this case if you execute it SM will fill its call and macro stacks and complain when it grabs more space. As before, it will think about it forever. More useful examples of recursive macros are compatible (see (undefined) [Mongo], page (undefined)), which starts

\[ \text{IF($?1 == 0) \{ compatible 1 RETURN \} ...} \]

providing a default value for its argument, and repeat which is discussed under DO.

To find how a particular macro is defined, type HELP macroname. For a listing of the first line of all currently defined macros, type
LIST MACRO

or

LIST MACRO x y

The optional x and y are the alphabetical (actually asciial ) range of macro names to list. As mentioned above, if VERBOSE is 0, macros starting with ## are not listed by this command. There is a macro ls defined as DELETE HISTORY LIST MACRO which will list macros without appearing on the history list. (Or you could overload list; see under overload in the index).

A related command is APROPOS pattern which lists all macros and help files\(^3\) whose names or initial comments contain the pattern, for example

APROPOS histogram

would list bar_hist and get_hist as well as the abbreviations hi and hist. If you wanted to find all macros starting with a single comment character which mentioned histogram you could say

APROPOS "^[a-z].*histogram"

where the double quotes prevent the #'s being interpreted as comment characters.

APROPOS ^[a-z]

will list all macros beginning with lowercase letters – this is similar to MACRO LIST a z, but pays no attention to the value of VERBOSE.

It is also possible to read macros in from disk, and in fact when SM is started, it tries to read the file ‘default’ in the directory specified by macro in the environment file ‘.sm’. The command to read a file of macros is

MACRO READ filename

Any line with a # in the first column is treated as a comment, and is echoed to the terminal if VERBOSE is greater than zero. All the currently defined macros may be written to a file with the command

MACRO WRITE filename

If the file exists, it will be overwritten (under VMS, a new version of the file will be written). Macros are written out in alphabetical order.

The command

MACRO WRITE macroname filename

writes the macro macroname to the file filename. This command remembers which file it last wrote a macro to, and if the current filename is the same then it appends the macro to the end of the file,

\(^3\) usually; this may not be available on Unix System V and VMS systems.
otherwise it overwrites it (or creates a new version under VMS) unless the filename is preceded by a +, in which case the macros will always be appended. This allows a set of related macros to be written to a file.

**MACRO DELETE filename**

undefined all macros which are defined in filename. This allows a file of macros to be read in, used and forgotten again. The difference between this command and MACRO macroname DELETE should be noted. The SAVE command is probably a better way of saving all current macros. The format of macros on disk is name nargs text, where nargs may be omitted if it is 0. Continuation lines start with a space or tab. See the files in the directory specified by macro in your `.sm` file for examples.

It is possible to define macros from the history list. The command

**MACRO name i j**

defines a macro name to be lines i to j inclusive of the history list, as seen using HISTORY. The opposite of this command, which places a macro upon the history list, is WRITE HISTORY name. Examples of these commands are the macros playback and edit_hist given in the section ‘A Simple Plot’. This way of defining macros can be convenient if you have created a useful set of commands on the history buffer, and now want to save it in a macro and go on to other things. Editing the playback buffer, and then changing its name to something else (see next paragraph) is a convenient way of saving it that implicitly uses this command.

Macros may be edited, using essentially the same keys as described above for the history editor. The command **MACRO EDIT name** starts up the editor, which works on one line at a time. The zeroth line has the format

```
0> Macro name : Number of arguments: n
```

where name is the name of the macro, and n is the number of arguments to the macro. If this line is changed, except to change name or n, any changes made to the macro will be ignored (note that the space after name is required). This can be useful if you decide that you didn’t want to make those changes after all. Changing name or n has the obvious effect, except that if n is negative the macro is deleted when you exit the editor. An empty macro is also deleted when you leave the editor (i.e. one with no characters in it, not even a space). The first line that you are presented with is the first line in the macro rather than this special one. Use CONTROL-N (or ↓ ) to get the next line, CONTROL-P (or ↑ ) to get the previous line. Carriage return (CONTROL-M) inserts a new line before the cursor, breaking the line in the process, while CONTROL-O inserts a new line before the current line. To save the changes and return to the command interpreter use CONTROL-X. All

---

4 you might prefer to use the macro ed which is equivalent to MACRO EDIT, but doesn’t appear on the history list and, if invoked without a macro name, will edit the same macro as last time. In addition, you can list the current macro with hm.
other keys have the same meaning as for the history editor (e.g. CONTROL-A to go to the beginning of a line). Note that CONTROL-K and CONTROL-Y can be used to copy lines, and that the bindings can be changed with EDIT or READ EDIT.

It wouldn’t be hard to write a macro that wrote out a macro to a file, invoked your favourite text editor, then read the new definition back in; see the macro `emacs_all` for ideas.

It is sometimes convenient to define a key to be equivalent to typing some string, such as playback or cursor. This can be done with the KEY command, whose syntax is `KEY key string`. If you just type `KEY <CR>` you’ll be prompted for the key and string. In this case you are not using the history editor to read the key, and you can simply hit the desired key followed by a space and the desired string, terminated by a carriage return. If you put `KEY`, `key` and `string` on one line you’ll probably have to quote the `key` with CONTROL-Q or ESC-q, or write the escape sequences out in the way used by EDIT. If this sounds confusing, here is an example. Type `KEY<CR>`, then hit the PF1 key on your terminal, type a space, and type "echo Hello World\N". Now just hit the PF1 key and see what happens. (The closing \N meant ‘and put a newline at the end’). These keyboard macros are not generally terminal independent, but they can be convenient. Definitions for the ‘PF’ keys on your keyboard can be made in a terminal-independent way by specifying the `key` as pfn or PFn where n is 1, 2, 3, or 4. If you always use the same terminal you might want to put some KEY definitions in your private startup file (see the discussion of startup2 in the section on useful macros). The current KEY definitions are listed with the LIST EDIT command, along with the other key bindings.
10 DO and FOREACH loops, WHILE loops, and IF statements

Related to the macro facility are the DO, FOREACH, and WHILE commands. IF is included here as a flow-of-control keyword.

The syntax for a DO loop is

```plaintext
DO variable = expr1 , expr2 [ , expr3 ] { command_list }
```

where the third expression is optional, defaulting to 1. The value of variable ($variable) is in turn set to expr1, expr1+exp3, ..., expr2, and the commands in command_list executed. Changing the value of $variable within the command list has no effect upon the loop. Do loops may be nested, but the name of the variable in each such loop must be distinct. A trivial example would be

```plaintext
DO val = 123, 123+10, 2 { WRITE STANDARD $val }
```

while a more interesting example would be the macro `square` discussed in the section on examples.

For loops within macros, it's often a good idea to make the loop variable local: `DEFINE val LOCAL DO val ... (see (undefined) [Define], page (undefined)).`

Because the body of the loop must be scanned (and parsed) repeatedly, loops with many circuits are rather slow. If at all possible you should try to use vector operations rather than DO loops. For example the loop

```plaintext
DO i=0,DIMEN(x)-1 {  
   IF(x[$i] >= 0) {  
      SET x[$i]=SQRT(x[$i])  
   } ELSE {  
      SET x[$i]=0  
   }  
}
```

is better written as

```plaintext
SET x=(x >= 0) ? SQRT(x) : 0
```

where the ternary operator ?: is discussed in the section on vectors (see (undefined) [Vectors], page (undefined)). If you only wanted the elements with x >= 0, you’d have said

```plaintext
SET x=SQRT(x) if(x >= 0)
```

As an alternative to DO loops, SM also has a general looping command, a while loop, for example

```plaintext
set i=0  
while {i < 10} {  
   commands  
   set i=i+1
```
is equivalent to a DO loop. In addition to being more flexible, WHILE loops may also be interrupted with the BREAK command, so the previous example could have been written (using variables instead of vectors)

```plaintext
define i 0
while{1} {
    echo Hi $i
    define i ($i+1)
    if($i == 10) { break }
}
```

Foreach loops are similar to do loops, with syntax

```plaintext
FOREACH variable ( list ) { command_list }
```

```plaintext
FOREACH variable { list } { command_list }
```

```plaintext
FOREACH variable vector { command_list }
```

where the list may consist of a number of words or numbers. A vector. Each element in the list (or of the vector) is in turn defined to be the value of $variable, and then the commands in command_list are executed, so that for example the commands:

```plaintext
FOREACH i ( one 2 three ) { WRITE STANDARD $i }
SET str = {one 2 three}
FOREACH i str { WRITE STANDARD $i }
```

will print out:

```
one
2
three
twice. Foreach loops may be nested, but again the variables must be distinct. You can delimit the list with {} so that it can include keywords (and other things that you want treated as strings such as 0.1 or $date), but even then you can't have the word delete in the list of a foreach. Sorry. It’s often helpful to make the foreach variable LOCAL (see (undefined) [Set], page (undefined)) inside macros, e.g.

```plaintext
DEFINE var LOCAL FOREACH var ...
```

If statements look similar, with syntax

```plaintext
IF ( expr ) { list } ELSE { list2 }
```

where the ELSE clause is optional, but if it is omitted the closing } must be followed by a newline (or explicit \n) (see (undefined) [Command Internals], page (undefined)).
If the (scalar) expression is true (i.e. non-zero), then the commands list are executed, otherwise list2 is, if present. It is also possible to use IF statements directly in plotting commands, for example `POINTS x y IF(z > 1/x).

It is possible to write general loops in SM by using tail-recursive macros. The simplest example would be

```sm
macro aa {echo hello, world\n aa}
```

which prints `hello, world` and then calls itself, so it prints `hello, world` and then calls itself, and so on until you hit `CONTROL-C`. The absence of a space before the closing brace is very important, as it allows SM to discard the macro before calling it again, which means that it won’t fill up its call stack and start complaining. A more interesting example is the macro `repeat` which repeats a given macro while the given condition is true. For example, if you say

```sm
set i=0 repeat aa while i < 10
```

it will print the integers from 0 to 9. With a few checks, bells, and whistles the macro looks like:

```sm
repeat 103    # Repeat a macro 'name' while the condition is true
# syntax: repeat name while condition
# Example: set i=0 repeat body while i < 10
if('$2' != 'while') {
    echo Syntax: $0 macro while condition
    return
}    
if(int((whatis($1)-4*int(whatis($1)/4))/2) == 0) {
    echo $1 is not a macro
    return
}
macro _$1 {
    if(($!!3) == 0) { return }
    $!!1
    _$!!1}
_$1
macro _$1 delete
```

and is one of SM’s default macros (type “help repeat” if you don’t believe me).

---

1 This was the only way before the days of WHILE loops (see [While], page (undefined)), and as the technique is interesting, we’ve kept this section in the manual.
11 The Help Command

There is an online help command. Typing HELP <CR> or HELP HELP gives a list of the help menu, or HELP keyword gives help with that keyword. The help menu consists of any files in the directory specified by the entry help in the environment file, so for example HELP data types the file data in that directory. For all cases except HELP help, the file is filtered through a version of the Unix utility ‘more’ which pages the file. When ‘more’ offers you a ‘...’ prompt, type ? to see your options. The same filter is used by e.g. LIST MACRO. If the command is HELP word, after HELP tries to print the file word, it looks to see if word is a macro, and if so prints its definition. If word is a variable, its value is then printed, and if word is also a vector HELP prints the dimension, followed by the help string associated with the vector vector_name (see section on vectors).

The APROPOS command is also useful when you need help. APROPOS string scans all the help files (if your operating system allows SM to do such things) and macro headers looking for the string. The string may actually be a pattern (see the description of APROPOS for details). If VERBOSE (see (undefined) [Verbose], page (undefined)) is zero only the lines from the help files matching the pattern are printed; if it is larger you are given a couple of lines of context on each side.

It is worth remembering that the index to this manual has an entry under weird, wherein are listed all sorts of strange happenings, with explanations and suggestions for workarounds.
12 Saving and Restoring a Session

If for some reason you want to stop a SM session for later resumption, and simply suspending
the process, ‘CONTROL-Z’, is not sufficient, (for instance the machine is going down), then the SAVE
command will write a file containing all your currently defined macros, variables, and vectors, along
with your current history buffer as the macro all. You will be prompted before each class of objects
is saved, or you can put the answers on the command line. The file is ascii, and can be edited if
you so desire. The filename defaults to ‘sm.dmp’ if not specified, or to the value of save_file from
your ‘.sm’ file. If some bug has crawled unbeknownst to us into SM, and results in some sort of
panic (such as a segmentation violation), a save file called ‘panic.dmp’ is written to your temporary
directory, no questions asked.

To restart, RESTORE filename will read them all back, using the same default file as for SAVE
if no filename is specified, and replace the current history buffer with the value of all from the
savefile. Of course, you could write a macro to preserve the current buffer (see the definition of
edit_all for hints). If the file wasn’t written by SAVE it is assumed to be a SM history file, one
of those written when you quit SM, and each line is assumed to be a command and written to the
end of the history buffer. This is generally useful when you started SM in the wrong directory. It
wouldn’t be hard to write a macro to use RESTORE to read a history file into a macro.

One problem with SAVE is that it saves lots of macros, including some of the system ones.
Specifically, all macros are saved except those beginning with “##”. This can be avoided with the
MACRO DELETE filename command, e.g. MACRO DELETE utils SAVE 1 1 1 MACRO READ utils. The
macro sav discussed under ‘useful macros’ will do this for you, and indeed not SAVE any macros that
have been read with the load macro. This is probably the best way to use the SAVE command. In
addition, sav also decides to save variables and macros, only prompting you about saving vectors.
sav is a good candidate for overloading (as save), and indeed is one of the macros redefined by the
set_overload command.
13 Vectors and Arithmetic

The basic unit of data in SM is the `vector', a named set of one or more numbers or strings. There is no limit to the number of vectors that may be defined. SM allows the user to read vectors from files or define them from the keyboard, to plot them and to perform arithmetic operations upon them. SM's string-valued vectors are less generally useful, but can be used for such purposes as labelling points on a graph.

To read a vector vec from a column of numbers in a file, where the filename has been specified using DATA and, possibly, the range of lines in the file to be used has been specified using the LINES command, use READ vec nn where nn is the column number, or READ { vec1 n1 vec2 n2 ... } to read many vectors. It is also possible to read a row, using READ ROW vec nn, where nn is the row number in the file. See READ for how to read a string-valued vector.

Instead of using simple column-oriented input it is possible to specify a format like those used by C's scanf functions (Fortran formats are not supported); if you provide your own format string you can only read numbers. For example, if your data file has lines like

```
1:12:30  -45:30:11
```

you could read it with read '%d:%d:%d %f:%f:%f' { hr min sec deg dmin dsec }.

A vector may also be defined as SET vec = x1,x2,dx to take on the values x1,x1+dx,...,x2, where dx defaults to 1 if omitted. If a scalar is encountered where a vector is expected, it is promoted to be a vector of the appropriate dimension; all other dimension mismatches are errors.

Example:

```
SET value = 5
SET x = 0, 50, 2
SET y = x
SET y[0] = 2*pi
SET y = value
SET x=0,1,.1 SET y=IMAGE(x,1.5)
SET s=str
SET s='str'
SET s[0]=1.23
SET x=1.23
SET s=x
SET s=STRING(x)
```

will define a scalar, value, with a value of 5, then define a vector, x, with 26 elements, valued 0, 2, 4, 6,..., 50, then define another vector, y with size 26 and the same values as x, set all 26 elements of y to have the value 5, set the first element of y to be 2 pi, set y to be a vector with one element with value 5, and finally set y to be a vector with the values taken from a horizontal cross-section from 0 to 1 through the current image. Unless a vector str is defined SET s=str is an error; to make s a string-valued vector use SET s='str'. SET s[0]=1.23 makes s[0] have the value "1.23"
(a string), as \( s \) is now a pre-existing string vector. An arithmetic vector \( x \) is then defined, and \( s \) is redefined as an arithmetic vector too – you must be careful when dealing with string vectors! Finally, we explicitly convert an arithmetic vector to a string-valued one with the \texttt{STRING} operator. This is a somewhat contrived example, designed mainly to illustrate the convenience of the \texttt{SET} command. The ability to set particular elements is mostly used in macros such as \texttt{smirnov2} which calculates the Kolmogorov-Smirnov statistic from a pair of vectors.

If you don’t have many data points, rather than type them into a file, and use \texttt{READ vec nn} to define a vector, you can use the command

\begin{verbatim}
SET vec = { list }
\end{verbatim}

For example

\begin{verbatim}
SET r = 0,10
\end{verbatim}

is equivalent to

\begin{verbatim}
SET r = { 0 1 2 3 4 5 6 8 9 10 }
\end{verbatim}

In fact, \{ list \} is an expression, so \texttt{SET vec = 2*{1 3 1}} is also legal. If the first element of a list is an integer, the vector is taken to be string-valued: \texttt{SET s={ William William Henry Steven \}} defines a 4-element string vector, or you can use a string in quotes: \texttt{SET s=<’1’ 2 3 4>} (if you used \texttt{SET s={’1’ 2 3 4}} the first element would be ’1’ rather than 1). Once a vector is defined, you can write it to a file for later study using the \texttt{PRINT} command.

A scalar may be an integer, a floating point number, a scalar expression, \texttt{DIMEN(vector)}, or \texttt{WORD[expr]}. The last two are the dimension of a vector, and an element of the vector with \texttt{expr} a scalar subscript. \textit{Note that subscripts start at 0 and that \([ \) \] not \( () \) are used to subscript variables}. The expression \texttt{WORD[expr]} is in fact allowed even if \texttt{expr} is not a scalar, in which case the result is a vector with the same dimension as \texttt{expr}, and with the values taken from \texttt{WORD} in the obvious way.

Once vectors are defined, they may be combined into expressions using the operators \(+\), \(-\), \(*\), \(/\), \(**\), \texttt{CONCAT} and the functions \texttt{COS()}, \texttt{SIN()}, \texttt{TAN()}, \texttt{ACOS()}, \texttt{ASIN()}, \texttt{ATAN()}, \texttt{ATAN2()}, \texttt{ABS()}, \texttt{DIMEN()}, \texttt{INT()}, \texttt{LG()}, \texttt{EXP()}, \texttt{LN()}, \texttt{SQRT()}, \texttt{STRING()}, \texttt{STRLEN()}, and \texttt{SUM()}. The meaning of most of these is obvious, \texttt{ATAN2} is like \texttt{ATAN} but takes two arguments, \texttt{x} and \texttt{y} and returns an angle in the proper sector. \texttt{DIMEN} returns the number of elements in a vector, \texttt{SUM} gives the sum of all the elements, \texttt{CONCAT} concatenates two vectors, \texttt{INT} gives the integral part of a vector, \texttt{STRING} converts a number to a string, and \texttt{STRLEN} gives the length of a string (in plotting units, not just the number of characters). \texttt{STRING} uses the same code as the axis-labelling routines, so \texttt{FORMAT} can be used to modify its behaviour; whether the x- or y-axis formats is used depends on whether the label is more nearly horizontal or vertical. An example would be

\begin{verbatim}
set x=3.08e16 define s (string(x)) relocate 0.5 0.5 putlabel 5 $s
\end{verbatim}
The precedence and binding are as for C (or Fortran), and may be altered by using parentheses (CONCAT has a binding just below + and −). All of these operators work element by element, so

\[ y = 2 + \sin(x) \]

is interpreted as

\[ y_i = 2 + \sin(x_i) \]

If there is a size mismatch the operation will only be carried out up to the length of the shorter vector and a message is printed; if VERBOSE is 1 or more, the line where the error occurred will be printed too. The constant PI is predefined.

You can also use \( \text{WORD([ expr [, ... ]])} \) as part of an expression, where \( \text{WORD} \) is a macro taking zero or more arguments. Suppose we define a macro \( \text{pow} \) with two arguments as

\[
\text{SET } y = 10 + 2\times\text{pow}(1 + x, 3)
\]

then the command

\[
\text{SET } y = 10 + 2\times(1 + x)**3
\]

is equivalent to \( \text{SET } y = 10 + 2\times(1 + x)**3 \).

In addition to these arithmetic operations, there are also logical operators \( == \) (equals), \( != \) (not equals), \( > \), \( >= \), \( < \), \( <= \), \( && \) (logical and), and \( || \) (logical or). The meanings of the symbols are the same as in C, and as in C the value 0 is false while all other values are true.

String vectors may only be concatenated, added, or tested for (in)equality. Adding two string-valued vectors concatenates their elements, so

\[{ a b c } + { x y z }\]

results in the vector ax by cz.

Testing equality for string vectors seems to cause some confusion. Consider

\[
\text{set str='a' b c d} \\
\text{if('a' == 'str') \{ ... \}} \quad \# \text{test if the strings 'a' and 'str' are equal} \\
\text{if('a' == str) \{ ... \}} \quad \# \text{test if the string 'a' equals the vector 'str'} \\
\text{if(a == str) \{ ... \}} \quad \# \text{test if the vector 'a' equals the vector 'str'}
\]

The second of these tests will succeed, but if you then try

\[
\text{if('b' == str) \{ ... \}} \quad \# \text{try to see if 'b' is an element of str}
\]

the test will fail as \( 'b' \) = \( \text{str} \) is the 4-element vector \{ 0 1 0 1 \} and only its first element is used by the \text{if} test; what you want is

\[
\text{if(sum('b' == str)) \{ ... \}} \quad \# \text{is 'b' an element of str?}
\]
There are also a number of less mathematical operations. If you have an IMAGE (see (undefined) [Image], page (undefined)) defined, you can extract a set of values using the expression IMAGE(expr,expr), where the two exprs give the coordinates where the values are desired. Note that this may be used as a way of reading large data files that are stored unformatted. The expression HISTOGRAM(expr : expr) can be used to convert a vector into a histogram. The second expression is taken to be the centres of the desired bins: bin boundaries are taken at the mean points (and points in the first expression lying on a boundary are taken to fall into the lower bin. Note the use of `:' not `,').

Vectors may be assigned to, using the syntax

\[ \text{SET vec} = \text{expr} \]

or

\[ \text{SET vec}[\text{expr}] = \text{expr} \]

or

\[ \text{SET vec} = \text{WORD(expr)} \]

or

\[ \text{SET DIMEN(vec)} = \text{number} \]

or

\[ \text{SET vec} = \text{expr1 IF(expr2)} \]

or

\[ \text{SET vec} = \text{expr1} ? \text{expr2} : \text{expr3} \]

The first form sets vec to have the value expr, element by element, vec is the name of the new vector. The form vec[expr] may be used to assign to an element of a vector, as usual the index starts at 0. Before you can use SET to assign values to the elements of a vector, you must create it using one of the other forms of the SET command.

If you want to define a vector to which you will subsequently assign values using SET vec[expr] = expr, you may use SET DIMEN(vec) = number which declares vec to be a vector of size number, and initialises it to zero. You can optionally supply a qualifier to the number, either a .f (the default), or a .s to specify that the vector is string valued.

If the IF clause is present, only those elements of expr1 for which the corresponding element of expr2 is true (non-zero) are copied into vec; in general vec will have a smaller dimension than expr1. The last SET statement (with ?:) again borrows from C. If expr1_i is true, then vec_i is set to expr2_i, otherwise it is set to expr3_i. In this form of conditional assignment, the dimension of vec is the same as that of the right hand side. It may look strange, but it can be just what you want.
Each vector also has a help field, which may be used to provide a string describing the vector. The field is set by

\[
\text{SET HELP vec str}
\]

and viewed by

\[
\text{HELP vec}
\]

or via the string-valued expression \text{HELP(name)}.

If \text{VERBOSE} is one or more, if a vector is arithmetic or string will also be noted. Vectors may be printed using the

\[
\text{PRINT [ file ] [format] \{ vec1, ..., vecn \}}
\]

command, where if the optional \text{file} is missing, the values are typed to the keyboard; if the optional \text{format} is omitted, a suitable one will be chosen for you. Any combination of string- and arithmetic-vectors may be printed. If a value exceeds 1e36, it is printed as a *. This is consistent with the convention used in reading data that a ‘missing’ number is represented as 1.001e36; see \text{READ} for details. Vectors may be deleted with the command

\[
\text{DELETE vec}
\]

and listed with the command

\[
\text{LIST SET}
\]

Vectors are listed in ascii order along with their dimension, and any help string specified using the \text{SET HELP} command.

Once you start writing (or using) complicated macros you’ll get bitten by the fact that a macro called by a macro called by a friend’s macro uses a scratch vector called \text{x} or \text{i}, and that this vector quietly overwrites your vector called \text{x} or \text{i}. To avoid this, conscientious macro writers make their vectors \text{LOCAL}.

After the command \text{SET x LOCAL} in a macro, any redefinitions of \text{x} within that macro, or any macros called by it, will be discarded when the macro exits. The vector isn’t strictly speaking local to the macro as it’s visible from macros that are more deeply nested, but the effect is similar. A word on caution: a macro can exit sooner than you expect; the classic example is

\[
cube 11 \quad \# \text{print a vector's cube for people we like}
\]

\[
define name local define name :
if(’$name’ != ’Thatcher’) {
    set x local set x = $1
    set x = x*x*x
    print The answer is $(x)
}
\]

\text{1 well, to be honest the LOCAL command’s a recent addition to SM so there are lots of macros out there that don’t do this}
Because the if might be followed by an else, the macro is read and popped from the input stack before it’s executed, causing confusion.

An IF clause has been added to the plotting commands, to allow only those elements of a vector which satisfy some condition to be plotted, for example

```
POINTS x y IF(z > 3*x)
```

Of course, you could have used the IF command and the regular POINTS command if you had preferred. In fact,

```
CONNECT x y IF(z > 3*x)
```

isn’t quite the same as

```
SET log = z > 3*x SET x = x IF(log) SET y = y IF(log)
CONNECT x y
```

as the former will only connect contiguous points.
14 Drawing Labels and SM’s \TeX Emulation

There are two separate ways to specify special characters to SM, by using a syntax very similar to \TeX (the type-setting system created by Donald Knuth that we used for this manual), or the traditional Mongo way. You might ask what are the advantages of \TeX? One is that sub- and super- scripts are handled much more naturally, making it much harder to type $M_V = -8$ when you meant $M_V = -8$. Another is that you no longer have to remember that $\theta$ is hidden in the Greek font as ‘q’, you can simply type $\theta$. A third would be that you may well know \TeX already.

If you want to make SM understand \TeX strings you should define the variable TeX_strings (if you put a line `TeX_strings = 1` in your `.sm` file this will be done automatically). You can, of course, undefine it at any time to revert to the old-fashioned strings described below. Using \TeX-style strings is strongly recommended by the authors; all future and most recent improvements to SM’s labels are only supported in \TeX mode.

If you want to change the default font used for labels, define the variable default_font; if you wanted to use the \oe (Old English) font you could either say `(DEFINE default_font oe)` interactively, or put a line in your `.sm file`: `default_font oe`. This affects axis as well as regular labels and only works if you use TeX_strings (of course).

For some devices with hardware fonts (for example, postscript printers or a Tektronix 4010 terminal), if expand is exactly 1, and angle is exactly 0, the hard fonts will be used for speed. Various strategies to defeat this are discussed below.

14.1 An Introduction to \TeX

(\TeXxperts should skip this section.) If you don’t know \TeX let’s start with an example:

\begin{verbatim}
label $\pi^{-21/2} = \{3\int e^{-x^2}\}dx$
\end{verbatim}

will print a well-known result (You’ll have to RELocate somewhere where the label will be visible first, of course). (If you want to try it now, you should be careful typing those ‘s, as they are special to the history editor, dealing with this is discussed below.) In this example the characters $\{, \}, \{\}$, and $^\sim$ are special (and so is $_-$ which wasn’t used). Postponing $\\backslash$ for the moment, $^\sim$ means ‘make the next group a superscript’, $_-$ means ‘make the next group a subscript’, where a group is either a single character, a single control sequence (wait a moment!), or a string enclosed in braces. So $A_a^{-\{SM\}}B$ would appear as $A_a^{SM\}B$. A $\\backslash$ can serve one of two functions, either turning off the special meaning of the next character (so $\\backslash_- is simply a $_- with no special significance), or to introduce a named ‘control sequence’. These fall into three groups, those that change fonts, those that serve as abbreviations for single characters (e.g. $\\backslash$ in the example), and those that are macros. The font changes persist until the end of the string, or the current group, whichever comes first.
The available fonts are ‘greek’, ‘old english’, ‘private’, ‘roman’, ‘script’, and ‘tiny’. They may be referred to either by a two-character control sequences (\gr, \oe, \pr, \rm, \sc, or \ti) or simply by the first character (e.g. \r for the roman font). In addition \i or \it can be used to make the current font italic (remember to use italics within \{\} so that their effect is limited!). The ‘bold’ font \b or \bf is makes the current font bold, and can be toggled off with a second \bf if you didn’t simply group it. I’d strongly recommend treating \bf like any other font change, and group them rather than relying on this toggling action.

The slant of \it letters can be controlled by the command sequence \slant, which takes an argument which is the tangent of the desired slope (i.e. it is the degree of shear). You can also compress all letters along the direction that they are being written using \condense; for example \{\slant0.4\condense0.5 Hello World\}.

You can alter the size of the letters by using an escape such as \6 which scales the current group (any font change is local to a group). \6 corresponds to multiplying the size by 1.2^6 or about 3, \-4 scales by 1/1.2^4 or 0.48. This is similar to the ‘magstep’ used in scaling fonts in TeX. These scale factors are in addition to the expansion produced by going up or down (^ or _), or setting EXPAND.

14.3 SM’s TeX Control Sequences

Other control sequences either consist of one non-alphabetic character, or else a name consisting only of letters, so \, or \palmtree is valid but \one2three is not. If a alphabetic name is followed by a space, the space is treated as simply delimiting the name and is discarded. For example, \AB\{\\alpha,\beta\ \CD\} will appear as \(AB^{\alpha_\beta}CD\) (note that the space after beta disappeared). How do you make just a few characters italic (script, old english, etc.)? Try ABC{\it DEF}GHI. You can’t read a subscript, and want it in ‘tiny’ font? Try \Lambda{\ti ab}. All of the Greek letters are defined, as \alpha-\omega, \Alpha-\Omega, there are various mathematical symbols (e.g. \int, \infty, or \sqrt), some astronomical (e.g. \AA for Á), and some miscellaneous characters (e.g. \snow to draw a snowflake). You can generate a complete list of definitions by saying load fonts TeX_defs.

Some of these definitions are more complex than just special characters, if you know TeX most of them should be familiar.

\bar str Draw a bar over str.
\border n str Add an n-pixel border of whitespace to str and draw it.
\centre
\center Center a string horizontally
\over str1 str2

Draw \texttt{str1} over \texttt{str2}, separated by a horizontal line. This isn’t nearly as sophisticated as \TeX{}’s \texttt{\over}, and never will be. It’s written in SM’s \TeX{} emulator which is pretty limited. If you are a \LaTeX{} user, SM’s \texttt{\frac} may be more familiar.

\phantom str

Don’t actually draw \texttt{str}, but take up as much space as \texttt{str} would have if you \textit{had} drawn it.

\smash str

Draw \texttt{str} but pretend that it took up no space.

\strut

Make the current formula have at least the depth and height of a parenthesis.

You can also define your own \TeX{} definitions by using the special command \texttt{\def\texttt{name}\texttt{\{value}}} inside a label. It produces no output, but defines \texttt{name} to expand to \texttt{value}. For example, I could define \texttt{\TeX} to produce \TeX{} by saying

\texttt{LABEL \def\TeX{T\raise-200\kern-20E\raise200X}}.

Once a definition has been made it is remembered forever (well, until you leave SM actually) whatever devices you plot on. You must make sure that all curly brackets are properly paired inside your definition. You can have arguments just like real \TeX{}, referred to as \texttt{#1}, \texttt{#2}, \texttt{#3} and so forth, for example

\texttt{\def\sub#1{_{#1}}}

Your SM guru can compile \TeX{}-definitions into the binary fonts file, instructions are given in the fonts appendix.

14.4 SM’s Extensions to \TeX{}

We have made a number of extensions to \TeX{} that are useful in a plotting package, but wouldn’t be especially valuable in a printed document. We have also distorted the meanings of some of \TeX{}’s control words; sorry.

\point n s
\apoint angle n s

Insert a points (such as would be drawn with \texttt{DOT}) into a label. The string \texttt{\point43} (or \texttt{\point 4 3}) will draw a point at the current position in the string, of \texttt{p}type ‘4 3’. This sequence, from the \texttt{\} to the \texttt{3}, is treated as a single character as regards things like subscripts. If you want to specify an angle, use something like \texttt{\apoint 45 4 0}.

\hrule width

Draw a horizontal line at the level of the current baseline, of length \texttt{width} in screen units. It will be multiplied by the current expansion.
\kern dx \kern # moves the current plot position by # horizontally, where the distance # is specified in screen units (the whole screen is 32768 across). It is multiplied by the expansion currently in effect, and may be positive or negative. See also \raise.

\line type length
\line inserts a line into a label, at about the level of the middle of a lower-case character. e.g. \line 1 1000 will draw a line of length 1000 (in screen units, so the screen is 32768 across), of ltype 1. See also \hrule.

\move dx dy
Move a group by (dx,dy), but don’t disturb SM’s current idea of where it is. This means that we can draw a line over a character with a string such as \move 0 300{\line 0 400}A. It is possible to use the commands such as \width to take the guesswork out of such commands, for example the definition of \bar is

\def\bar#1{\move0\advance\height{#1}by100{\rule\width{#1}}#1}

\raise dy \raise # moves the current plot position by # vertically, where the distance # is specified in screen units (the whole screen is 32768 across). It is multiplied by the expansion currently in effect, and may be positive or negative. See also \kern.

\rule depth height
Draw a vertical line at the current position of depth d and height h (and width 0) in screen units. Dimensions are multiplied by the current expansion.

There are also a number of control sequences that can be used whenever a number is expected (by \kern, \line, \move, or \raise); for an example of their use see \move in the preceding table.

\advance num1 [ by ] num
Increment first number (which can be of the form \width{...}) by the second. The by is optional.

\depth{...}
The depth a group would have if it were drawn.

\divide num1 [ by ] num2
Divide the num1 by num2/1000. As for \advance, num1 and num2 need not be ‘simple’ numbers but can be combinations of widths, advances, and so on. The by is optional.

\height{...}
The height a group would have if it were drawn.

\multiply num1 [ by ] num2
Multiply the num1 by num2/1000. See \divide for the lack of restrictions on num1 and num2. The by is optional.

\width{...}
The width a group would have if it were drawn

If you want to know the dimensions of the string that you have just drawn (or just not drawn, q.v. PUTLABEL 0) you can look at the internal variables $sdepth, $sheight, and $slength.
14.5 Caveats and Cautions when using \TeX

Now for a few caveats: Firstly, because `\n` is a newline, you must type `\nu` or `"\nu"` to get a \nu. Secondly, the superscript character `^` is special to the history editor, so to type it interactively you must quote it with the `quote_next` key (usually `CONTROL-Q` or ESC-q, i.e. type `CONTROL-Q^`). Alternatively, you could change your history character to some under-used character such as `%` or `'#' (which is the solution that I use: you can choose a new character such as `'#' by simply putting a line `history_char '` in your `'.sm' file). Thirdly, \TeX (and our pseudo\TeX) are rather verbose and labels may not fit on one line. The solution is to continue the line by ending it with a `\`. This is probably best done within a macro, as the continuation line won’t appear on your history list if typed at the prompt. You can currently have about 25 continuation lines (2000 characters).

A final point will only worry \TeXies, namely that the emulation isn’t perfect: for example `\sum_i` won’t put the \i beneath the summation symbol. Some of the other discrepancies were listed in the previous section.

14.6 How to Stop the Device using its Fonts

If \Expand is set to exactly 1, and ANGLE is exactly 0, then SM will use hardware fonts, when available, in writing labels. This is faster, but can lead to two styles of labels in one plot which is ugly.

There are various ways to trick SM into always using its own fonts: you can say say “ANGLE 360”, or use a `\0` to select a font with (explicitly) no expansion. To affect the axis tick labels too, using the \Axis or BOX commands, you’ll have to say “\Expand 1.0001” or somesuch.

Rather than always expanding your plots, you could ask your SM Guru to edit the ‘graphcap’ file to prevent a given device (usually a printer) from ever using hardware fonts. Tell her to see ‘Graphcap’, page ‘Graphcap’. If she won’t oblige, you can define your own device in your own graphcap file, and put yours first in the `'.sm' file. For example, my `'.sm' file includes the line

```
+graphcap /d/rhl/graphcap
```

and the file ‘/d/rhl/graphcap’ looks like:

```
# Private overrides for RHL:
#
postscript|postscript + no hardware fonts:\
 :TB@:TE@:TC=postscript:
```

Then I set `$printer` to `postscript` (also in `'.sm') and all is well.

An alternative is to specify the device as

```
DEVICE postscript :TB@:TE@:tc=postscript:
```
which is perhaps simpler (you’d just define your value of \texttt{printer} properly).

### 14.7 Old-style Labels

If you insist on using old-style labels (which are still the default), here’s a quick summary. Type \texttt{\textbackslash a} or \texttt{\textbackslash\textbackslash a} to change to font \texttt{a} for one character (first form) or permanently (second form). The possible fonts are \texttt{g, o, p, r, s,} and \texttt{t} for ‘greek’, ‘old english’, ‘private’, ‘roman’, ‘script’, and ‘tiny’ respectively. In addition, the pseudo-fonts \texttt{u} and \texttt{d} move text ‘up’ and ‘down’ respectively, and \texttt{i} produces ‘italic’ (actually just slanted) characters. Size changes are just like any other font change, so \texttt{\textbackslash 6} and \texttt{\textbackslash -4} will affect one character and the rest of the string respectively. This is really somewhat simpler than it sounds - try

\begin{verbatim}
label \texttt{\textbackslash g p \textbackslash u\textbackslash -21/2\textbackslash d = \textbackslash 3\textbackslash g:e\textbackslash u-x\textbackslash u2\textbackslash d\s dx}
\end{verbatim}

Note that ‘tiny’ is a misnomer, it is (nowadays) just a font that look better if you need small letters ( \texttt{\textbackslash t\textbackslash -6} will produce a shrunken ‘tiny’ font, just like the old days). Spaces are treated differently in different fonts, as a greek space is a negative space (i.e. a backspace), and a script space is only half as wide as a normal space.
15 Getting Hardcopies of Plots

There isn’t really any need for this section because SM doesn’t distinguish between hardcopy devices such as laser printers and other devices such as graphics terminals, except that it saves up plotting commands for hardcopy devices and sends them all when you are finished. There are, however, hard and easy ways to do anything and this section is intended to make your life a little simpler.

When a device that can produce hardcopy is closed the plot is sent off to the printer (using the command given as SY in the device’s graphcap entry). The only way to close a device is to open another, any other, so it is just as good to say dev x11 as it is to say hardcopy dev x11 as the macro hardcopy does no more than open the null device. So one way to produce a plot is to say

```
device postscript
plotting commands
device x11
```

There are many different printers available, and even if you are using a postscript printer you might want portrait (postport) or landscape (postland) plots, so it is traditional to put the name of the desired printer into a variable printer. It is so traditional, indeed, that it can be done with a line such as

```
printer postport
```

in your ‘.sm’ file.

The two commonest incantations are probably

```
device $printer
playback
device x11
```

or

```
device $printer
my_macro
device x11
```

which can be simplified to hcopy and hmacro my_macro respectively. The former can be given a single history number (e.g. hcopy 12) to only make a hardcopy of the one command, or a range of numbers (hcopy 1 12) to plot those lines (inclusive). The latter, if you omit the name of the macro, will prompt you to create a temporary macro that is then printed. If you want to make a hardcopy of the last line you have a choice, either hcopy -1 or hmacro, and then use the history editor to retrieve the desired line.

Some sites have many hardcopy devices of the same type, in which case they usually set up the SY command to expect an argument which is the name of the desired printer. You can deal with this by including it in your printer variable: define printer "postscript latypus" but this
can be a nuisance, especially as unix already has a special (environment) variable PRINTER that specifies your default printer. The resolution is that both hcopy and hmacro are quite careful; if you have an SM variable PRINTER it is taken to be your default printer; if you don’t have one they look for one in your ‘.sm’ file, if they don’t find one there they look for an environment (VMS: logical) variable. If all of these fail they take the first argument (hcopy) or last argument (hmacro) to be the name of the printer.

So if you have a PRINTER variable anywhere, hcopy and hmacro macro_name will work as before, if you don’t then you’ll have to say hcopy printer_name or hmacro macro_name printer_name.
16 Overloading Keywords

Sometimes you might wish that SM’s authors had decided to make a command behave a bit differently, for instance that ERASE or QUIT didn’t appear on the history list, or that SAVE deleted all the system macros before saving your environment. Of course, you can (usually) write macros to get around these annoyances, but you can’t easily give them the same names as the original commands (for these examples the macros are called era, q, and sav).

It is possible to change the meaning of keywords (to ‘overload’ them), but it can be confusing, primarily because your new commands may not behave the same way that this manual claims. For example, if you were perverse, you could define points to mean QUIT. Another danger is that you could end up with a recursive call – for instance if you wrote your own version of box that did all sorts of cunning things, then drew a box. If you said box in your macro, then overloaded the keyword, you’d have a macro that called itself. If you tried to use it, nothing would happen for a while, and then you’d start getting messages about “extending i/o stack” until you hit CONTROL-C. Or if you redefined help to mean DELETE HISTORY HELP (in upper case to avoid recursive calls, and in case delete has been overloaded), then set help vec Help string won’t work (you’d have to use set HELP vec ...).

Despite these warnings, overloading the meaning of SM’s keywords can be very convenient. There are two sets of system macros that do just this, the compatibility ones (see undeﬁned [Mongo], page undeﬁned), and one called set_overload that is described below.

In addition to the semi-trivial use of overloading to allow you to type erase not era, it is possible to add extra functionality to simple commands. For example, set_overload deﬁnes window to save the window parameters in variables, and box then uses these values to label appropriate axes in touching boxes. Another example is that (when overloaded) lines saves the line numbers used, so that you can write a macro to print the top 10 lines of a file (it’s called head).

So how do you do it? The command OVERLOAD keyword # will remove the special meaning of lowercase keyword if # is non-zero, or reinstate it otherwise. You can still use the uppercase form – you can’t overload that. So now that e.g. box has no special meaning you can define it to be a macro. What the set_overload macro does is to deﬁne new meanings for a number of keywords, the new deﬁnitions are in the macro ﬁle ‘overload’. If you intend using them (and I do all the time) you should look at this ﬁle. You can get them loaded by default by having a line overload 1 in your ‘.sm’ ﬁle. If you don’t like some, e.g. box, you can simply say OVERLOAD box 0 in your private startup ﬁle (see ‘private initialisation’) which is run after the system startup.

Most of the changes are benign, but not all. For example, the new deﬁnition of relocate allows expressions, but it’ll break if you try to say relocate ( 100 1000 ) to move to absolute screen coordinates. You can still say RELOCATE ( 100 1000 ) of course, and that’s why most of the system macros are actually written in uppercase. The deﬁnition of box (actually bo, which box calls) may seem very complex, but it has to deal with box \n as well as box 1 2, and it must know if you have
used the WINDOW command. This brings up another point – if you overload keywords, you could slow SM down. It isn’t that overloading is inefficient, it’s just that the macros that replace the old keywords may do a good deal of work, box is a case in point. Even when the macro is short and to the point, it’s still extra work to parse the original word and find its value as a macro.
17 Examples of Useful Macros

When you start SM the directory specified as macro in your `.sm` file is searched for a file `default`, and then the macro `startup` from that file is executed. At the time of writing of this manual, `startup` was defined as:
As this macro is executed every time that you run SM, let us consider it in some detail. After setting the prompt, it looks for entries for a number of variables in your `.sm` file. Some (such as
printer) are simply DEFINEd, while some (such as TeX_strings) are only DEFINEd if they have a non-zero value. Because some of the values might not be numeric, the comparison is forced to be done on strings by enclosing the quantities in single quotes. An entry prompt is interpreted as a primary prompt, mostly for compatibility with the use of $prompt2 to set the secondary prompt. If device is defined it is used to set the default plotting device, and both it and printer are used by a couple of macros (hcopy and hmacro) that produce hardcopy. The variables TeX_strings and default_fonts are used in producing labels (see (undefined) [Fonts], page (undefined)). Because \TeX uses ^ for superscripts, we allow you to put a history_char line in `.sm' to specify a character to use rather than ^ for history (I use '). If you use 0, or omit the value (so it is set to 1), no history character is defined to replace ^. The variable file_type is used by the IMAGE command to determine the file format that you use (e.g. C, or unformatted fortran).

Startup doesn't have to check that macro was successfully defined as it must have been found for startup to have been read in the first place. Macro specifies where to look for macro libraries, and startup next sets the variable mfiles containing the names of some of the system macros to be loaded, and reads them. The macro load defined below also maintains the mfiles list, as does unload. It is used by the sav macro, which is discussed below the main listing of macros that follows. We also set some variables used by the id macro.

As part of our effort to be nice to users, if you have uppercase 1 in your `.sm' file, we also load the uppercase macros. Next startup overloads some keywords if overload is in your `.sm' file, reads a file of keybindings (if edit is given in `.sm'), and finally tries to read a second optional macro directory macro2, and executes a macro startup2 if it's defined (that's what the macro is_set is checking). This is quite important, as it provides a way to customise SM to your personal taste without convincing the local SM guru that your taste should be foisted on everyone. If you want a prompt that is different, or a definition of q that just quits without asking questions, you can get them by using macro2. You can see that it is possible to tailor SM pretty much as you wish without changing a line of code, just by playing with the startup macro.

SM provides various compatibility macros, and some to package often-used functions. The macro files `stats' and `utils', which are read when SM is started, provide various useful macros, a few of which are presented here. To see a current list, either look at the files directly, set VERBOSE to zero and list all the macros, look at the listing in this manual (see (undefined) [Libraries], page (undefined)), or use lsm to list macro files (this only works if you are running Unix; try lsm demos). We give here a number of macros taken from the files `default', `mongo', `stats', and `utils'. Among those not listed are those like lin defined to be lines that are pure abbreviations, those like xlogarithm defined as SET x=lg(x) which provide functionality in a perhaps familiar form, and many more like those that are given here which provide enhancements (e.g. the macro barhist). A discussion of a few of the more interesting or obscure follows. Keywords are written in uppercase, because you might have been playing tricks with overloading the lowercase equivalents. Many of these macros, in fact all from `default' and `mongo', start with ## so as not to show up in listings
made when \texttt{VERBOSE} is 0, and so as not to be \texttt{SAVED}. In the interest of brevity we have omitted most of these initial comments.

cumulate 2 \hfill \# Find the cumulative distribution of $1$ in $2$
\begin{verbatim}
DEFINE sum 0 SET $2=0*\!$1 SET HELP $2$ Cumulation of $1$
DO i=0,DIMEN($1)-1 {
    DEFINE sum ( $sum + $1[$i] )
    SET $2[$i] = $sum
}
define sum delete
da 1 DATA "$1"
del1 1 DELETE HISTORY \n
device $1$ DEVICE $1$
dra 2 \hfill \# Draw, accepting expressions
define 1 ($1$) define 2 ($2$) draw $1$ $2$
edit_hist \hfill \# Edit the history list
del1 MACRO all 0 100000 \hfill \# define "all" from buffer
WRITE STANDARD Editing History Buffer\nMACRO EDIT all \hfill \# do the editing
DELETE 0 100000 \hfill \# empty history buffer
WRITE HISTORY all \hfill \# replace history by "all"
era del1 ERASE
gauss 1 \hfill \# Evaluate a Gaussian : $N(\text{mean},\text{sig})$
SET $0 = 1/(\text{SQRT}(2*\pi)*\text{sig})*\text{EXP}(-((1-\text{mean})/\text{sig})**2/2)$
get 2 \hfill \# Syntax: get i j. Read a column from a file.
\hfill \# Name of vector is jth word of line i.
DEFINE nn READ $1$ $2$ echo reading $nn\nREAD $nn$ $2$
SET HELP $nn$ Column $2$ from $data_file$
DEFINE nn DELETE
hardcopy \hfill \# close old device
DEVICE nodevice
\end{verbatim}
### hcopy 13

```
## hcopy [printer] [l1] [l2] Make hardcopy of playback buffer
# optionally specify printer ($1) and desired lines ($2-$3)
# if the printer ($1) is omitted (i.e. $1 is missing or a
# number), it will be taken from the value of the environment
# variable PRINTER, if defined.
IF($?printer == 0) {
    DEFINE printer ? { what kind of printer? }
}
IF($?1) {
    IF(WHATIS($1) == 0) { # a number
        if($?2) { DEFINE 3 $2 }
        DEFINE 2 $1
        DEFINE 1 DELETE
    }
}
IF($?1) {
    DEVICE $printer $1
} ELSE {
    IF($?PRINTER == 0) { DEFINE PRINTER : } # which one?
    IF($?PRINTER) {
        DEVICE $printer $PRINTER
    } ELSE {
        DEVICE $printer
    }
}
IF($?2 == 0) {
    DEFINE 2 0 DEFINE 3 10000
} ELSE {
    IF($?3 == 0) { DEFINE 3 $2 }
}
playback $2 $3 \n DEVICE $device
bell
```
## hmacro [macro] [printer] Make hardcopy of a macro

# If only 1 argument is present, it is taken to be the printer
# unless an environment PRINTER variable is defined, when
# that’s used as a printer, and the argument is taken to be
# a macro. If no macro is specified, make a temp one

IF($?printer == 0) {
    DEFINE printer ? { what kind of printer? }
}

IF($?2 == 0) { # only one arg
    IF($?PRINTER == 0) { DEFINE PRINTER : }
    IF($?PRINTER) {
        DEFINE 2 $PRINTER
    }
}

IF($?1) {
    IF($?2) { # 2 args
        DEFINE _mac $1
        DEFINE _temp 0 # no temp macro
    } ELSE { # 1 arg, take as printer
        DEFINE 2 $1 # printer
        DEFINE _temp 1 # need temp macro
    }
} ELSE { # no $1
    IF($?2 == 0) { DEFINE 2 " " }
    DEFINE _temp 1 # need temp macro
}

IF($_temp) {
    DEFINE _mac _mac
    echo "Create temporary macro, exit with ^X"
    MACRO EDIT $_mac
    IF(is_set($_mac,1) == 0) {
        DEFINE _mac DELETE DEFINE _temp DELETE
        DEFINE _test DELETE
        RETURN
    }
}

DEVICE $printer $2
$_mac \n DEVICE $device
IF($_temp) { MACRO $_mac DELETE }
DEFINE _mac DELETE DEFINE _temp DELETE bell
Chapter 17: Examples of Useful Macros

load  # load macros in default directory
DEFINE macro :  # get default directory
MACRO READ " crack $!macro" $1  # read macro file
IF($?mfiles == 0) {
  DEFINE mfiles $1
} ELSE {
  DEFINE 3 0
  FOREACH 2 ( $mfiles ) {
    IF('$2' == '1') { DEFINE 3 1 }
  }
  IF($3 == 0) { DEFINE mfiles < $mfiles $1 > }
}

load2 1  # load macros in (second) default directory
DEFINE macro2 :  # get directory
IF($?macro2) {
  MACRO READ " crack $!macro2" $1  # read macro file
} ELSE {
  echo Directory macro2 is not defined
}

logerr 3  # logerr x y error, where y is logged, and error isn't
SET _y = 10**$2
SET d_y = LG(_y + $3) - $2 ERRORBAR $1 $2 d_y 2
SET d_y = $2 - LG(_y - $3) ERRORBAR $1 $2 d_y 4
DELETE _y DELETE d_y

lsq 15  # do a least squares fit to a set of vectors
# syntax: lsq x y [ x2 y2 [rms]] Fit line y2=$a*x2+$b to x y
# optionally, calculate rms residual as $rms
# see rxy to find product moment correlation coeff,
# and spear for Spearman's corr. coeff., and significance
SET _n = DIMEN($1)  # number of points
SET _sx = SUM($1)  # sigma x
SET _sy = SUM($2)  # sigma y
SET _sxy = SUM($1*$2)  # sigma xy
SET _sxx = SUM($1*$1)  # sigma xx
DEFINE a ( (_n*_sxy - _sx*_sy)/(_n*_sxx - _sx*_sx) )
DEFINE b ( (_sy - $a*_sx)/_n )
IF($?3 && $?4) {
  SET $4=$a*$3+$b
  IF($?5) {
    DEFINE $5 ( sqrt(sum(($a*$1 + $b - $2)**2)/dimen($2)) )
  }
}
FOREACH v ( _n _sx _sy _sxy _sxx ) { DELETE $v }
playback  ## define "all" from buffer, and run it  # with args, only playback those lines  IF($?1 == 0) {  
    DEFINE 1 0 DEFINE 2 10000  
  } ELSE {  
    IF($?2 == 0) { DEFINE 2 $1 }  
  }  
del1 MACRO all $1 $2 all  
read_old 1  
del1 # read a Mongo file onto the history buffer  
READ OLD temp $1  
WRITE HISTORY temp MACRO temp { DELETE }  
rel 2  
# Relocate, accepting expressions  
define 1 ($1) define 2 ($2) relocate $1 $2  
reverse 1  
# reverse the order of a vector  
SET _i = DIMEN($1),1,-1 SORT < _i $1 > DELETE _i  
sav 1  
# Save to a file $1, don’t save from files ‘$mfiles’  
_save $1  
_save 1  
# Save to a file $1, don’t save from files ‘$mfiles’  
del1  
FOREACH 2 ( $mfiles ) { MACRO DELETE "$!macro"$2 }  
DEFINE 2 0 define 2 ? { save vectors? }  
SAVE "$!1" 1 $2 1  
FOREACH 2 ( $mfiles ) { MACRO READ "$!macro"$2 }  

Cumulate is given as a way not to write macros if you can help it (in this case, I couldn’t). A better example is reverse which reverses the order of the elements in a vector without resorting to a DO loop.

The macro da could have been defined to be DATA, but there are various special characters that appear in filenames; try data /usr/spool/junk or data disk$data:[ETHELRED]junk.dat. The macro da provides a set of double quotes to escape these unwanted interpretations. Incidentally, da "/usr/spool/junk" won’t work.

DELETE HISTORY deletes the last command on the history buffer, so del1 alone on a line will delete itself, which can be used to prevent a command from appearing on the history list, for example changing devices with dev; dev also defines a variable device which is used by the hcopy and hmacro macros to make hardcopies, while returning you to your initial device. The startup macro listed above also sets device, if it is specified in your ‘.sm’ file. You should be careful not to include more than one del1 macro in any macro that you write yourself, as each del1 will remove a command from history and you could find commands mysteriously disappearing.

Gauss evaluates a Gaussian, e.g. SET x=-3,3,0.05 SET g=gauss(x) lim x g box con x g, an example of using a macro like a function definition. (For this example to work, you have to define variables mean and sig first).

There is an example of reading variables from files and using them in macro get. This reads a word from a line in a file with the DEFINE nn READ i j command, which sets $nn to be the jth
word on line i of the current data file. This variable is then used to **READ** a vector, which is given the appropriate name. So if a file looks like:

```
This is an example file
alpha beta gamma delta
1 10 0.1 1e1
2 20 0.2 1e2
3 30 0.3 1e3
4 40 0.4 1e4
5 50 0.5 1e5
```

then the commands

```
GET 2 1 GET 2 2 GET 2 3 GET 2 4
```

will read ‘1 2 3 4 5’ into vector **alpha**, ‘10 20 30 40 50’ into **beta** and so forth. Note that

```
DEFINE READ file_id 1 LABEL $file_id
```

will write out ‘This is an example file’ to the current position of the plot pointer (see, e.g. **RELOCATE**). Incidentally, **READ ROW omega 5** would set the vector **omega** to have values ‘3 30 0.3 1e3’.

The macros **hcopy** and **hmacro** make hardcopies of, respectively, the playback buffer and a macro. Both assume that the variables **device** and **printer** are set. **device** is set from your `.sm' file and by the dev macro; **printer** is assumed set in `.sm' (See ‘startup’ file above). If all is well, the macros switch to device **printer** (with an argument to specify which sub-printer is desired. We have so many laser printers here...), execute the desired commands, and return to the initial **device**. When the **printer** device is closed, hardcopy will result. Note the use of \n to ensure that no nasty things happen; if there were no \n and the buffer ended with LABEL Hi, the plot could appear with a label Hi device tek4010. The versions of **hcopy** and **hmacro** given here accept a variable number of arguments (‘13’ means up to 3 arguments). The first (if present) is taken to be the desired laser printer\(^1\), the next argument is the number of the first line that you want played back, and the third is the last line number. (If you omit both line numbers you’ll get the whole buffer; if you omit the second you’ll just get the one line). The macro sees what it has been given by using $? to see which variables are defined, and acts accordingly. **hmacro** is somewhat similar, except that if you omit an argument it is taken to be the macro name, and a temporary one is created for you. The **playback** macro deals with its arguments in a similar way, and is discussed further in the examples at the end of this section.

**load** enables you to read a set of macros from a directory specified as **macro** in your environment file. **Load2** is similar, but it looks in directory **macro2**. The macro **unload** (not listed here) will undefine the loaded macros. Note that a list of all the loaded macros is kept in $mlist, which is used by the sav macro to avoid SAVEing lots of system macros. sav is written in terms of a macro _save so that it won’t itself be forgotten (by **MACRO DELETE**) while in the middle of saving macros.

\(^1\) Actually, if the environment (VMS: logical) ‘.sm’ variable PRINTER is defined the macros pretend that it was the first argument, so you can simply type **hcopy**.
If you want to put errorbars on logarithmic plots, \texttt{logerr} is the macro you've been looking for. It calculates the correct length for the errorbars, and plots them de-logging and re-logging as appropriate.

The macros \texttt{rel} and \texttt{dra} illustrate a method of using expressions, rather than numbers, in the commands \texttt{RELOCATE} and \texttt{DRAW}. There are Good Reasons why \texttt{DRAW} won't accept an expression directly (see (undefined) [Command Internals], page (undefined)). These macros exploit the fact that the arguments to a macro are whitespace delimited, so a string such as \texttt{1+2/$x}} comprises one argument. Redefining the arguments means that the macros don’t have to define, and then delete, a couple of variables to hold the expressions.

Now that you have had your appetite whetted, we strongly recommend that you take the time to look through the other macros that are available (see (undefined) [Libraries], page (undefined)). Otherwise how would you know that there are macros to draw arrows on plots, do KS and Wilcoxon tests on vectors, and a host of other good things?
18 More Examples of Macros

In all these examples, we’ll use the \texttt{del1} macro discussed above to keep commands off the history list. Let’s start with a Fourier series, to demonstrate SM’s ability to manipulate vectors. All keywords are capitalised for clarity. Start SM, choose a plotting device (with the \texttt{dev} macro), and erase all the commands on the history (or playback) buffer with \texttt{DELETE 0 10000}. Then type the following commands:

\begin{verbatim}
SET px=-PI/10,2*PI,PI/200
SET y=SIN(px) + SIN(3*px)/3 + SIN(5*px)/5 + SIN(7*px)/7
SET y=(y>0)?y:0
LIMITS -1 7 y
BOX
CONNECT px y
\end{verbatim}

The vector \texttt{px} could just as well have been read from a file. You should now have a part of a square-wave, truncated at 0.

Now consider a simpler way of doing the same thing. For the present, clear the history buffer again (\texttt{DELETE 0 10000}), and type:

\begin{verbatim}
SET px=-PI/10,2*PI,PI/200
SET y=SIN(px)
DO i=1,3 {
  SET val = 2*$i + 1
  SET y = y + SIN(val*px)/val
}
DELETE val
LIMITS -1 7 y
BOX
CONNECT px y
\end{verbatim}

Here we use a vector \texttt{val} to save a value, an equivalent (but slower) loop using SM variables would be

\begin{verbatim}
DO i=1,3 {
  DEFINE val (2*$i + 1)
  DEFINE y = y + SIN($val*px)/$val
}
DEFINE val DELETE
\end{verbatim}

That is all very well if you only ever wanted to sum the first four terms of the series. Fortunately there is a way to change this, using the macro editor. First define a macro consisting of all the commands on the history list:

\begin{verbatim}
\texttt{del1 MACRO all 0 10000}
\end{verbatim}

will define the macro \texttt{all} to be history lines 0-10000. (You need the \texttt{del1} to avoid having the \texttt{MACRO all 0 10000} in your macro). Then you can edit it using
del1 MACRO EDIT all

do when you have made the desired changes (e.g. changing \texttt{DO i=1,3} to \texttt{DO i=1,20}) use \texttt{CONTROL-X} to leave the editor and return to the command editor. Now you could type \texttt{all} to run your new macro, or put it back onto the history list. To do the latter, delete the commands now on the history list (the now-familiar \texttt{DELETE 0 10000}), then \texttt{del1 WRITE HISTORY all} to put the macro \texttt{all} onto the list. Now the \texttt{playback} command will run all those commands, and produce a better squarewave. (As discussed in a moment, \texttt{playback} is a macro so type it in lowercase, unless you have defined your own \texttt{PLAYBACK} macro.)

This ability to edit the history buffer is convenient, and there is a macro provided called \texttt{edit_hist} which goes through exactly the steps that we took you through. The trick of including a \texttt{del1} in macros is pretty common, for example \texttt{h} is defined as \texttt{del1 HELP} so that it won’t appear on the history list. The macro \texttt{playback} is rather similar to \texttt{edit_hist}, but instead of editing and then writing \texttt{all}, it executes it. We discussed the possibility of just playing back a limited number of lines while talking about \texttt{hcopy}, just say \texttt{playback n1 n2}.

Now that you have a set of commands which produce a Fourier plot, it would be nice to define a macro to make plots, taking the number of terms as an argument, and then free the history buffer for other things. After a playback, the macro \texttt{all} is defined, so let’s change its name to \texttt{square}. There is a macro \texttt{ed} defined more-or-less as \texttt{del1 MACRO EDIT}, so type \texttt{ed all} to enter the macro editor. Use \texttt{↑} or \texttt{CONTROL-P} to get to line 0 and change the number of arguments from 0 to 1, and the name of the macro from \texttt{all} to \texttt{square} (the space between the name and the : is required.) Then go to the \texttt{DO i=1,20} line, and change 20 to \$1$. Exit with \texttt{CONTROL-X}, clear the screen with \texttt{era} and type \texttt{square 10}. Now how do you save your nice macro? \texttt{WRITE MACRO square filename} will write it to file ‘filename’, and next time you run SM \texttt{MACRO READ filename} will define it. In fact there is a command \texttt{SAVE} to save everything which can be a mindless way of proceeding. A macro similar to this Fourier macro called \texttt{square} is in the file \texttt{demos} in the default macro directory (and was used to produce the top left box of the cover to this manual). To try it yourself, type something like \texttt{load demos square 20}. ($20$ is the number of terms to sum.)

If your wondering why \texttt{ed} is only ‘more-or-less’ defined as \texttt{del1 MACRO EDIT}, it’s because the real \texttt{ed} checks to see if you have provided a macro name, and if you haven’t it edits the same macro as last time.

But enough of macros which fiddle with the history buffer. Here are four sets of macros which do useful things, and may give some idea of the power available. First a macro to use the values of a third vector to mark points, then one to do least-squares fits to data points, then a macro to join pairs of points, and finally some macros to handle histograms and Gaussians. These macros are given in the format that SM would write them to disk (ready for a \texttt{MACRO READ}), with the name, then the number of arguments if greater than 0, then the body of the macro.

First the points.
alpha_poi 3  # alpha_poi x y z. Like poi x y, with z as labels for points
DO i=0,DIMEN($1)-1 {
    DEFINE _x ($1[$i]) DEFINE _y ($2[$i])
    RELOCATE $_x $_y
    DEFINE _z ($3[$i])
    PUTLABEL 5 $_z
}
FOREACH v ( _x _y _z ) { DEFINE $v DELETE }

Here we use the temporary variables _x _y _z to get around restrictions on expressions in RELOCATE commands. Note the DO loop running from 0 to DIMEN($1)-1, produced by array indices starting at 0 not 1. If you wanted to use character strings as labels, this could be done by using the DEFINE READ command, but this would be a good deal slower as SM would have to rescan the file for each data-point. The top right box of this manual’s cover was made using this macro. The use of alpha_poi (and also the macro file called ascii) has been superseded by the introduction of string-valued vectors into SM. Nowadays you’d simple read the column that you want to label the point with as a string (e.g. READ lab 3.s), set the point type to that string (e.g. PTYPE lab), and plot the points as usual (e.g. POINTS x y).

The least-squares macro makes heavy use of the SUM operator. It could be used to find the dimension of a vector too, but only clumsily, and DIMEN is provided anyway. The macro is:

lsq 4  # Do a least squares fit to a set of vectors
# Syntax: lsq x y x2 y2  Fit line y2=a*x2+b to x y
DEFINE _n (DIMEN($1))  # number of points
DEFINE _sx (SUM($1))  # Sigma x
DEFINE _sy (SUM($2))  # Sigma y
DEFINE _sxy (SUM($1*$2))  # Sigma xy
DEFINE _sxx (SUM($1*$1))  # Sigma xx
DEFINE a (($_n*_sxy - $_sx*_sy)/($_n*_sxx - $_sx*_sx))
DEFINE b (($_sy - $a*$_sx)/$_n)
SET $4=$a*$3+$b
FOREACH v ( _n _sx _sy _sxy _sxx ) {DEFINE $v DELETE }

This does a linear fit, leaving the coefficients in $a and $b. It could be easily generalised to deal with weights, fits constrained to pass through the origin, quadratics...

Our third example connects pairs of points. This was written to deal with a set of data points before and after a certain correction had been applied.

pairs 4  # pairs x1 y1 x2 y2. Connect (x1,y1) to (x2,y2)
DO i=0,DIMEN($1)-1 {
    DEFINE _x ($1[$i]) DEFINE _y ($2[$i])
    RELOCATE $_x $_y
    DEFINE _x ($3[$i]) DEFINE _y ($4[$i])
    DRAW $_x $_y
}
FOREACH v ( _x _y ) { DEFINE $v DELETE }
After the introduction of vectors for \texttt{ANGLE} and \texttt{EXPAND} (in version 2.1) this macro can be rewritten to be much faster:


csvs
tables
datasets

\begin{verbatim}
pairs 4 # pairs x1 y1 x2 y2. connect (x1,y1) to (x2,y2)
DEFINE 6 { ptype angle expand aspect }
FOREACH 5 { $!!6 } { DEFINE $5 | }
FOREACH 5 {fx1 fx2 fy1 fy2 gx1 gx2 gy1 gy2} {
  DEFINE $5 DELETE
}
ASPECT 1
SET _dx$0=($3 - $1)*($gx2 - $gx1)/($fx2 - $fx1)
SET _dy$0=($4 - $2)*($gy2 - $gy1)/($fy2 - $fy1)
PTYPE 2 0
SET _a$0=(_dx$0 == 0 ? (_dy$0 > 0 ? PI/2 : -PI/2) : 
  (_dy$0 > 0 ? ATAN(_dy$0/_dx$0) : ATAN(_dy$0/_dx$0) + PI))
ANGLE 180/pi*_a$0
EXPAND SQRT(1e-5 + _dx$0**2 + _dy$0**2)/(2*128)
POINTS (($1 + $3)/2) (($2 + $4)/2)
FOREACH 5 { $!!6 } { $5 $$5 DEFINE $5 DELETE }
FOREACH 5 ( _a _dx _dy ) { DELETE $5$0 }
\end{verbatim}

Note how \texttt{DEFINE name |} is used to save things like the angle and expansion, while \texttt{DEFINE name} \texttt{DELETE} is used to ensure that the up-to-date versions of things like \texttt{fx1} are used (i.e. that they \texttt{haven't} been \texttt{DEFINEd} with a \texttt{!}). The name of the macro ($0$) is used to make unique vector names, or at least names like \texttt{_dxpairs} that are very unlikely to be in use.

SM allows you to plot a pair of vectors as a histogram, but what if you have only got the raw data points, not yet binned together? Fortunately, SM can do this binning for you. Consider the following macro:

\begin{verbatim}
get_hist 6 # get_hist input output-x output-y base top width
# given $1, get a histogram in $3, with the centres of the
# bins in $2. Bins go from $4 to $5, with width $6.
SET $2 = $4+$6/2,$5+$6/2,$6
SET HELP $2 X-vector for $3
SET $3=0*$2 SET HELP $3 Histogram from $1, base $4 width $5
DO i=0,DIMEN($1)-1 {
  DEFINE j ( ($1[$i] - $4)/$6 )
  SET $3[$j] = $3[$j] + 1
}
DEFINE j DELETE
\end{verbatim}

Since this was written, a new feature was added to SM, the expression \texttt{HISTOGRAM(x:y)}, to make histograms. The macro we discussed above can now be written much more efficiently as:
get_hist 6    # get_hist input output-x output-y base top width
# given $1, get a histogram in $3, with the centres of the
# bins in $2. Bins go from $4 to $5, with width $6.
SET $2 = $4+$6/2,$5+$6/2,$6
SET HELP $2 X-vector for $3
SET $3=HISTOGRAM($1:$3)
SET HELP $3 Histogram from $1, base $4 width $5

Suppose that your data is in vector x, for want of a better name, and it has values between 0 and 20. Then the command

get_hist x xx yy 0 20 1

will produce a histogram in yy, bin centres in xx, running from 0 to 20 with bins 1 unit wide. So you could plot it with lim xx yy box hi xx yy, and maybe it looks like a Gaussian. So what is the mean and standard deviation? The command

stats x mean sig kurt echo $mean $sig $kurt

will answer that, and find the kurtosis too. (Macro stats consists of lines such as define $2 ( sum($1)/dimen($1) ) ). Then we could use the macro gauss to plot the corresponding Gaussian,

set z=0,20,.1 set gg=gauss(z) set gg=gg*dimen(x) con z gg

The bottom left box of the cover was made this way. What if you don’t like the way that the histogram looks? Try the macro barhist. Now, if you wanted to plot a lognormal, you’d have to write your own macro, and you could use SORT to find medians and add another macro to utils, followed by one to find Wilcoxon statistics... (Since this was written a wilcoxon macro was donated to stats).
19 What Quotes What When

This chapter is not really needed as all of its contents can be found elsewhere in this manual, but as people manage to become confused anyway, here’s a summary. There are three ways in which characters can alter SM’s behaviour: they can affect the way that characters and keywords are interpreted, they can be special to the grammar, and they can perform both functions. If you are confused, you might find a verbosity of four or five helpful.

"..." Turn off the expansion of variables, the significance of mathematical operators such as / or ;, and the recognition of keywords. For example, after DEFINE rhl Patricia, /data/$rhl would be interpreted as four tokens (/, data, /, and Patricia), while "/data/$rhl" is only one (/data/$rhl). Note that in the former case, the data will be taken to be part of a DATA command, and may well lead to a syntax error. If you need to force a variable to be expanded within double quotes, use an exclamation mark: "$!rhl". Double quotes have no syntactical significance.

Incidently, "12" is a number as the closing " is read before the characters 12 are parsed. You need to say "12 " to make 12 a word; in a different package you might call that a bug.

'...' Single quotes surround strings which may contain white space (spaces or tabs), characters such as + or /, or keywords. They don’t affect variable expansion, so you have to enclose them in double quotes if you want to protect them. Of course, you must make sure that you are not quoting the single quotes – use ’"$abcd"’ rather than '"$abcd"’ . Strings are significant to the grammar so only use single quotes where they are needed. For example DATA ’my_file’ is a syntax error, and SET s='abc' and SET s=abc mean quite different things.

{...} Turn off all interpretation of special characters and keywords, just like double quotes. In fact, braces even turn off the expansion of $!var, to expand a variable within braces you need to say $!!var but you only very seldom need this. Braces have syntactical significance, delimiting lists. Wherever you can use braces you can use angle brackets.

<...> Almost identical to {...}, but don’t turn off variable expansions. In fact, <> don’t always turn off keyword interpretation – specifically they only do so in str_list’s (if you want to know what this means you’ll have to read SM’s grammar in file ‘control.y’). In practice you’ll probably only meet this if you try saying Foreach f < quit when ahead > { echo $f }.

(...) Parentheses don’t turn off any sort of expansion, but can have syntactical significance. You are most likely to see this in DEFINE var ( 1 + 2 ) where the parentheses tell SM to evaluate the expression before defining the variable var as 3. Note that DEFINE var < 1 + 2 > defines var as 1 + 2 .
$\text{name}$ Expand name as a variable. Expansion is turned off within single and double quotes and within braces. Because the expansion happens before the parser sees the input, variables cannot have any syntactical significance as the parser never knows about them. This means that variables could be used to make SM look like something quite different; for example after \texttt{DEFINE begin \{ " DEFINE end \}"}, you can say

\begin{verbatim}
MACRO hi $\text{begin}$ echo Hello World $!!\text{end}$
\end{verbatim}

(This is a little tricky. The spaces in \texttt{DEFINE begin " { " are needed so that SM is still in quote mode when it processes the {. You can probably figure out why I need to say $!!\text{end}$ – the !! should be a Helpful Hint.)

$(\text{expr})$ Evaluate the expression expr and substitute the resulting value. This is identical to \texttt{DEFINE temp ( expr ) $\text{temp}$}, but much more convenient.

As a reasonably complex example, try to guess the output from:

\begin{verbatim}
DEFINE hi {"$!(\text{'Hello'}')" World>} DEFINE hello $\text{hi}$ echo :$\text{hi}$:$\text{hello}$:
\end{verbatim}

If you are not sure, try it (you might find \texttt{VERBOSE 5} helpful)$^1$.

$^1$ The {} turn off all expansions, so $\text{hi}$ is defined to be \texttt{"$!(\text{'Hello'}')" World>}. The statement defining $\text{hello}$ then becomes \texttt{DEFINE hello \"$!(\text{'Hello'}')" World>}, and the ‘!’ ensures that the expression ‘Hello’ is evaluated and substituted; ‘Hello’ is a string valued vector, admittedly with only one element, so it evaluates to the five characters ‘Hello’ and the statement becomes \texttt{DEFINE hello <Hello World>} which means that $\text{hello}$ is defined as $\text{Hello World}$. Apart from being a red herring, the colons are only there to make it easy to see which variable expands to what.
20 Reserved Keywords

Keywords are reserved, so don’t try to use them as macro names or whatever. You can use the lowercase forms if you explicitly ask to be allowed to overload them. The control words are:

WORD STRING FLOAT INTEGER ( ) { } \n ! APROPOS BREAK CHDIR DEFINE DELETE DO
EDIT ELSE FOREACH HELP HISTORY IF KEY LIST LOCAL MACRO OLD OVERLOAD PRINT
PROMPT QUIT READ RESTORE RETURN ROW SAVE SET STANDARD TABLE TERMTYPE USER
VERBOSE WHILE WRITE

Arithmetic words are:

ABS ACOS ASIN ATAN ATAN2 CONCAT COS DIMEN EXP FFT INT LG LN PI RANDOM
SIN SQRT STRLEN SUM TAN WHATIS POWER_SYMBOL [ ] = + - * ** / < > | & ? :

SM plotting keywords are:

ANGLE ASPECT AXIS BOX CONNECT CONTOUR CTYPE CURSOR DATA DEVICE DOT DRAW
ERASE ERRORBAR EXPAND FORMAT GRID HISTOGRAM IMAGE LABEL LEVELS LIMITS
LINES LOCATION LTYPE LWEIGHT MINMAX NOTATION POINTS PTYPE PUTLABEL RANGE
RELOCATE SHADE SORT SPLINE TICKSIZE WHATIS WINDOW XLABEL YLABEL

With the exception of POWER_SYMBOL (which is equivalent to **) these are described below, with the convention that arguments between square brackets are optional. This has nothing to do with their use in subscripting arrays!
21 Glossary of Terms used in this Manual

.sm See Environment File.

Environment File
When you start SM it looks in a file (by default called ‘.sm’) to discover where to find files that it needs (such as the default macros, the help files, and the font files). You can access variables stored in the environment file yourself, although this is probably seldom done by non-gurus. For more details, see (undefined) [Environment Variables], page (undefined).

Expression
An SM expression is something that can appear on the right hand side of a SET command. More specifically, it is something that can appear as part of the right hand side of a SET command (this excludes implied do loops: SET x=1,10,2). Expressions may also appear in other contexts, such as in the ANGLE command, or in DEFINE name (expression). A formal definition of an expression is given by the YACC grammar in ‘control.y’ as the non-terminal symbol expr.

Filecap
Binary files produced by different programmes (and languages, and even compilers) are not identical, Fortran ‘unformatted’ files being a glaring example. A filecap file is a database used to describe the byte-by-byte format of binary files, to allow SM to read them (using the IMAGE command).

Graphcap
There are a very large range of graphics terminals (and laser printers and so forth) in this world, and each seems to have its own set of commands. A graphcap file is a database that is able to describe (almost) all of these dialects, allowing SM to plot on a wide range of devices.

History
SM remembers commands as you type them, so that you can repeat them or modify them (which includes correcting mistakes). The set of remembered commands is referred to as the history buffer.

List
The word list is used in a few places in the manual in the specific sense defined by the YACC grammar in ‘control.y’. A list is simply a list of words or numbers, and its meaning depends on the context. For example, SET x=3*(1 2 3) will set the vector x to be 2 4 6, while MACRO hi { echo Hello} will define the macro hi.

Macro
A macro is an abbreviation for a set of commands, so instead of typing a complicated sequence of commands you can simply type the macro’s name. You can either think of macros as new commands in their own right or as subroutines.

Mongo
Mongo is a plotting package written by John Tonry, and widely used in astronomy departments. SM’s command language was based on Mongo’s, and we have provided some support for an easy transition from Mongo to SM.
p_expr A parenthesised expression. Many commands expect to be passed the name of a vector, but will accept an expression in parentheses; for example in the command `POINTS x (y + 2/z),` \((y + 2/z)\) is a p_expr.

s_expr A scalar expression. This is a term used in some of the command descriptions; examples would be 210157, \(x[12]\), or \(x\). In the latter case, the first element of the vector \(x\) would be used, so it is equivalent to \(x[0]\).

Stdgraph SM uses the stdgraph device driver for most devices, using the information in the graphcap file (see (undefined) [Graphcap], page (undefined)).

String A string to SM is a sequence of characters enclosed in single quotes: `This is a string`. Strings are primarily used in vector expressions, but are also used in a few other places (e.g. to specify a format for a `PRINT` or `READ` command). Note that characters in double quotes are not strings to SM, merely characters protected from variable expansion.

Termcap Terminals come in many, many, avours and types. Their peculiarities are described by a termcap file, allowing SM’s command editor to run on (almost) any terminal.

TeX TeX is a typesetting language developed by Donald Knuth. We provide an emulation of certain parts of TeX’s mathematics mode in SM’s label commands.

Overload A keyword (such as `DEFINE` or `SET`) is said to be overloaded if its meaning has been changed. Usually this will be by adding functionality, rather than by actually changing what it does.

Variable A variable is an abbreviation for a sequence of characters, and may appear anywhere that the characters in question could appear. Even if the variable contains a number (e.g. \(6.62559e-34\)) it is still just a characters, although SM may choose to treat them as a number in some contexts (e.g. the right-hand side of a `SET` command).

Vector A set of one (actually, zero) or more elements. The elements can be either numerical (floating point) or strings. Vectors are SM’s primary data type. Do not confuse a 1-element vector (a scalar) with a variable (see (undefined) [Variables], page (undefined)).

YACC The SM command language is written in a language called YACC (which is supported on Unix systems). We have provided an implementation of YACC called Bison in the SM distribution.
Chapter 22: Command Reference

This is the reference manual to SM’s commands

**Syntax: ABORT**

ABORT closes the current device without producing any hardcopy. If you are writing an output file it will be removed. You are left talking to the null device, so you probably want to follow ABORT with a DEVICE command.

**Syntax: ANGLE expr**

For most purposes only the first element of the expr is used, let’s call it \( D \) as it’s an angle in degrees.

ANGLE will cause text from LABEL to come out \( D \) degrees anti-clockwise from horizontal. It also causes points to be rotated counter-clockwise by \( D \) degrees.

If \( D \) is non-zero it will force axis and other labels to be written with SM’s internal fonts, and will overrule the tendency to put x-axis labels horizontal, and y-axis labels vertical.

For plotting points the full vector of values is used, with the point rotated by the value of expr. If more points are specified than the dimension of expr, the first element will be used for the excess.

The current value of ANGLE is (almost) always available as the variable $angle (it is one of the special variables that are affected by the DEFINE variable | command).

**Syntax: APROPOS pattern**

Apropos lists all macros whose name or introductory comments match the given pattern. Probably the most common use for the command is simply to look for a word – e.g. APROPOS histogram.

If your system supports it, APROPOS will also search the help files for the given pattern (in this case matches may not extend over more than one line). If VERBOSE is zero only the line containing the match is printed; if VERBOSE is one or more then a couple of lines on each side of the match are printed too. If the pattern matches more than once each match will be printed, merged together if appropriate and separated by line of dashes otherwise. If you use ‘q’ to stop looking at the help files APROPOS will immediately proceed to search the macros.

The pattern is a slightly restricted version of a normal Unix regular expression, specifically:

.. Matches any character except \n.

APROPOS
[...] Matches any of the characters listed in the [ ].
    If the first character is a ^ it means use anything except the range specified (in any other position ^ isn't special)
    A range may be specified with a - (e.g. [0-9]), and if a ] is to be part of the range, it must appear first (or after the leading ^, if specified). A - may appear as the special range ---.

^ Matches only at the start of the string. Note that you must quote the ^ with an ESQ-Q if you use it as your history character – look in the index under history to learn how to change it.

$ Matches only at the end of a string.
\t Tab
\n Newline
. (any other character) simply escapes the character (e.g. \^)
* Any number of the preceding character (or range)
? One or more of the preceding character or range

By default searches are case insensitive, but you can make searching sensitive to case by deleting the variable case_fold_search (you can do this by putting a line case_fold_search 0 in your `.sm' file if you so desire).

The name and the comments are searched separately, so you could list all macros beginning with a, b, c, d, e, or z by saying

APROPOS ^[a-ez]

(which works because all comments start with a #), or

APROPOS "^#[^#]"

to list all macros that start with a single # (the quotes are needed to stop the #’s from being treated as comment characters).

---

Syntax: ASPECT A

Set the aspect ratio (Y/X) to be A; This is used in drawing characters and points and is reset when a new DEVICE command is issued.

The current values of the x- and y- dimensions of the current device are (almost) always available as the variables $nx and $ny, and the current aspect ratio is $aspect (they are some of the special variables that are affected by the DEFINE variable | command).
If $A$ is exactly 0, the current aspect ratio is printed – this is equivalent to `echo $aspect` and is retained as a curiosity.

Usually the aspect ratio is calculated by SM to make characters look right (and to make square points square), but it is sometimes useful to override this, especially when positioning labels on graphs that will be plotted on printers of different aspect ratios.

It might be worth going through an example. Suppose that you want to make a plot that really is square when printed; how should you proceed?

The available plotting area runs from 0–32767 on each axis. So a plot set up as

```
location 5000 20000 5000 20000
```

will have the same aspect ratio as the plotting device, in general rectangular. We can write this as

```
define len 15000 # axis length, SCREEN units
location 5000 $(5000 + $len) 5000 $(5000 + $len)
```

if we feel sophisticated.

The variable `$aspect` tells you the Y/X ratio of the current device; so the location

```
location 5000 $(5000+$len) 5000 $(5000+int($len/$aspect)) box
```

will be a square box. Of course, you’d probably really want to say

```
if($aspect > 1) {
  location 5000 $(5000+int($aspect*$len)) 5000 $(5000+$len) box
} else {
  location 5000 $(5000+$len) 5000 $(5000+int($len/$aspect)) box
}
```

There is a problem with this; the sizes of points and labels are varied to look right with the current aspect ratio. This means that a

```
putlabel 5 Hello World
```

command that looks fine on the screen of your workstation will look awful on the printer. That’s where the `ASPECT` command comes into play: on your workstation lie to SM and tell it that the aspect ratio is that of the printer. How do you do that? Well, the slick way is to say

```
macro aspect_as_device 1 {
  DEVICE $1
  define 1 $aspect
  ABORT
  DEVICE $device
  ASPECT $1
}
```

which assumes that you use a version of the device command that saves the current device as `$device`; the macro `dev` does this, and you can overload `device` to mean `dev`. Then you can say

```
ASPECT
aspect_as_device postport
to force the same aspect ratio as the postport device.; your plots will look ugly on the screen but beautiful when printed.

Arithmetic

Arithmetic is allowed on vectors and scalars in SM, using the following operators, where expr is a expression, s_expr is a scalar expression (e.g. a number), and vector the name of a vector.

Nonary (?):

PI Pi

Unary:

expr -expr Change sign ABS(expr) Absolute value
ACOS(expr) Arcosine ASIN(expr) Arcsine
ATAN(expr) Arctangent COS(expr) Cosine
CTYPE() Return CTYPEs DIMEN(vector) Dimension of a vector
EXP(expr) Exponential FLOAT(expr) Convert to float
GAMMA(expr,expr) Incomplete gamma fn INT(expr) Integral part
LG(expr) Log_10 LN(expr) Log_e
RANDOM(s_expr) Random numbers SIN(expr) Sine
SQR(expression) Square root STRING(expr) Convert to a string
SUM(expr) Sum_i expr_i TAN(expr) Tangent
VECTOR[expr] Elements of an array { list } Set vector to list
< list > Set vector to list ( expr ) Raise precedence

Binary:

expr + expr Add expr - expr Subtract
expr CONCAT expr Concatenate expr * expr Multiply
expr / expr Divide expr ** expr Exponentiate
expr & expr Bitwise AND expr | expr Bitwise OR
expr << expr Bitshift left expr >> expr Bitshift right
expr % expr Modulus ATAN2(expr_y,expr_x) Atan2

(note that a bitwise XOR may be achieved as | - &).

There are also some special operators:

HISTOGRAM(expr:expr) Construct histogram
IMAGE(expr,expr) Extract cross section (x, y coordinates)
IMAGE[expr,expr] Extract cross section (x, y indices)
expr1 ? expr2 : expr3 expr2 if expr1 is true, else expr3
DO(s_expr, s_expr) Implicit DO loop
DO(s_expr, s_expr, s_expr) Implicit DO loop with increment

GAMMA returns an incomplete Gamma function, so GAMMA(a,infy) = 1.

ARITHMETIC
RANDOM generates a vector of s_expr random numbers in the range [0,1]. If you don’t specify a seed (using SET RANDOM) one will be chosen for you based on the current time.

ATAN2 is the same as C’s function of the same name, and is equivalent to ATAN(y/x). It gives a result in the range -pi -- pi dealing correctly with divisions by zero.

CTYPE returns a vector of red + 256*green + 256^-2*blue, giving the currently defined colours; CTYPE(STRING) returns their names (see <undefined> [Strings], page <undefined>).

D0 generates a range of values, e.g. set x=do(1,5) sets x to have the values 1 2 3 4 5; this is the same as set x=1,5; but set y=100 + sin(pi*do(0,10)/10) is more interesting. You can specify an increment, so do(5,1,-1) is 5 4 3 2 1.

The expression VECTOR[expr] results in a vector of the same dimension as the expr, with elements taken from VECTOR (i.e. VECTOR[INT(expr_i)]). See, for example, the macro interp.

You can also use WORD([ expr [ , . . . ] ]) as part of an expression, where WORD is a macro taking zero or more arguments.

The precedences are what you’d expect, with ** being highest, then *, / and %, then + and -, then CONCAT, then the bitwise and logical operators, and finally ?: has the lowest priority of all. You should not assume any precedence between logical and bitwise operators, because if you do you’ll be fooled (e.g. 1||0 | 0x6 is 7, but 0x6 | 1||0 is 1); if you use parentheses all will be well (1||0 | 0x6) is 1 and 0x6 | (1||0) is 7).

If you have defined an image file with the IMAGE command, IMAGE(expr,expr) is an expression to extract values from your image. The two expressions give the x and y values where the image is to be sampled. For example set x=0,1,.01 SET z=IMAGE(x,0.5) will extract a horizontal cross section through an image. As an alternative, you can use (0-based) indices to extract the values with IMAGE[expr,expr]; there are examples under IMAGE (see <undefined> [Image], page <undefined>.

HISTOGRAM(expr1:expr2) constructs a histogram from a vector, where the data is in expr1, and expr2 (which must be sorted) gives the location of the bins. If the values of expr2 are equally spaced, the ‘location’ of the bin means the centre; if they are not, a bin is defined by saying that points with value (e2[i-1] + e2[i])/2 <= x < (e2[i] + e2[i+1])/2 go into the ith bin. Note that values on bin boundaries go into the higher bin.

a ? b : c is very useful if you want to treat some value of an expression specially. You could do this with a loop but ?: is much faster; for example

set y = lg(x > 0 ? x : 1e-37)  
set y = sqrt(x >=0 ? x : 0)

Due to the way that SM evaluates these expressions you may see warnings from the parts of the expressions that are not used (i.e. where the logical expression is false). You can turn down the
verbosity, of course, or you could try sending mail us mail to see if we can’t fix it (but it isn’t easy, or else we’d have done it already).

See ‘Logical’ for the logical operators, ‘Strings’ for string operators, and ‘whatis’ for finding out if strings are numbers, words, vectors, or whatever.

---

**Syntax:**

<table>
<thead>
<tr>
<th>Syntax</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AXIS A1 A2 VSMALL VBIG AX AX ALEN ILABEL ICLOCK</td>
<td>Makes an axis labeled from A1 to A2 at location AX, AY, length ALEN. The first form (with VSMALL and VBIG) specifies the values where you want small and big ticks explicitly; if you specify the string-valued vector VLAB it will be used to label the big ticks. The third form is more obscure: If ABIG &gt; 0 use that for spacing of large ticks. If ASMALL &lt; 0 make a logarithmic axis, if ASMALL = 0, do the default. (See TICKSIZE for more on the meaning of negative ASMALL and/or ABIG). If ASMALL &gt; 0 try to use that for the spacing of small ticks.</td>
</tr>
<tr>
<td>AXIS A1 A2 VSMALL VBIG VLAB AX AY ALEN ILABEL ICLOCK</td>
<td></td>
</tr>
<tr>
<td>AXIS A1 A2 ASMALL ABIG AX AY ALEN ILABEL ICLOCK</td>
<td></td>
</tr>
</tbody>
</table>

**ICLOCK** is used for (too) many purposes; it’s treated as three integers of 1, 2, and 1 bits respectively.

<table>
<thead>
<tr>
<th>ICLOCK &amp; 0x1:</th>
<th>Control the ticks orientation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Anticlockwise from the axis</td>
</tr>
<tr>
<td>1</td>
<td>Clockwise from the axis</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(ICLOCK&gt;&gt;1) &amp; 0x3:</th>
<th>Control the tick direction:</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Ticks are perpendicular to axis</td>
</tr>
<tr>
<td>1</td>
<td>Ticks are vertical</td>
</tr>
<tr>
<td>2</td>
<td>Ticks are vertical</td>
</tr>
<tr>
<td>3</td>
<td>Don’t draw any ticks</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(ICLOCK&gt;&gt;3) &amp; 0x1:</th>
<th>Control which side of the axis the ticks appear:</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>The same size as the labels</td>
</tr>
<tr>
<td>1</td>
<td>The opposite side to the labels</td>
</tr>
</tbody>
</table>

If you prefer not to think in terms of bitwise operators, this can be written as if ICLOCK is even the ticks are anticlockwise on the axis, if odd they are clockwise. You usually want the ticks perpendicular to the axes, and this is what you get with ICLOCK 0 or 1; if it is 2 or 3 the ticks are vertical, and if 4 or 5 they are horizontal. The labels are on the opposite side of the axis from the ticks unless you add 8 to the numbers given above.

For example, the following commands are equivalent to BOX:

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANGLE 0</td>
<td></td>
</tr>
<tr>
<td>AXIS $fx1 $fx2 0 0 $gx1 $gy1 ($($gx2-$gx1) 1 $(0</td>
<td>8)</td>
</tr>
<tr>
<td>AXIS $fx1 $fx2 0 0 $gx1 $gy2 ($($gx2-$gx1) 0 $(1</td>
<td>8)</td>
</tr>
<tr>
<td>ANGLE 90</td>
<td></td>
</tr>
</tbody>
</table>
except that I set ICLOCK’s 0x8 bit to draw the ticks outside the box).

If you want to label the bottom axis of some plot only at prime points try

```plaintext
SET b={1 2 3 5 7 11 13 17 19} SET s=0,20
AXIS 0 20 s b
```

If you have used LIMITS to scale the axes and LOCATION or WINDOW to move them, you could say something like

```plaintext
AXIS $fx1 $fx2 s b $gx1 $gy1 $($gx2-$gx1) 3
```

An example of using your own string valued labels would be:

```plaintext
set s=1,7,.5 set b=1,7 set labs={ o B A F G K M }
LIMITS 1 7 0 0
AXIS 0 10 s b labs
```

which works as expected. If you don’t have a shift key and try using lower case (obafgkm) you’ll be surprised as all the letters are not at the same level (as they don’t all have the same height). The easiest way to deal with this is to make them all the same height:

```plaintext
set labs={ o b a f g k m } + '\strut'
```

(a strut is a TeXism that has the height and depth of a parenthesis; I’m afraid that you do have to escape the \ in the string). If that leaves too much space try:

```plaintext
set labs='\move 100' + { o b a f g k m } + '\strut'
```

I think that you get the point.

If you want more control over placement and sizes of axis labels and ticks, you can force SM to draw them separately:

```plaintext
EXPAND 0.5
AXIS $fx1 $fx2 0 0 $gx1 $gy1 $(g2-$gx1) 0 $(1<<3)
EXPAND 1.44
AXIS $fx1 $fx2 0 0 $gx1 $gy1 $(g2-$gx1) 1 $(3<<1)
```

gives smaller-than-usual ticks outside the box with larger-than-usual labels (you could have used define default_font "2" to achieve the latter)

The distance of labels from axes is controlled by the SM variable label_offset; increase it to move them further away.

Rather than use AXIS to draw all of your axes, it may be easier to use BOX with some 3’s to disable its axis-drawing habits. You’ll still get a box, but no ticks or labels. For example,
 LIMITS 0 1 0 10 BOX 1 2 0 3 TICKSIZE 0 0 -1 0 BOX 3 3 1 3

will label the y-axis with both linear and logarithmic axes.

This was changed in V2.1: To specify logarithmic axes you should now specify the logarithms, just as you do to BOX. For example, to draw a logarithmic axis running from 1 to 1000, specify A1 as 0 and A2 as 3, rather than 1 and 1000.

See NOTATION if you want to control the use of floating point or exponential notation. You can control the font used by setting the variable default_font. If you want your positive and negative exponents to line up define the SM variable line_up_exponents; if it’s 1 they’ll be padded with a space, if 2 or more, with a + (you can do this in your ‘.sm’ file).

Syntax: BOX [ INTEGER1 INTEGER2 [ INTEGER3 INTEGER4 ] ]

BOX puts axes around the plot region, labelling the lower and left according to the values set by LIMITS and TICKSIZE. If arguments INTEGER1 and INTEGER2 are included (default 1 and 2) they are used as ILABEL arguments for the lower and left axes (see AXIS). An ILABEL of 0 means to omit axis labels, 1 produces labels parallel to the axis, 2 perpendicular, 3 omits both labels and tickmarks, and 4 omits the axis entirely. INTEGER3 and INTEGER4 are used for the top and right axes.

If you want to change the font used for axis labels, define the variable default_font, either interactively (DEFINE default_font oe), or by putting a line in your ‘.sm’ file: default_font oe. This affects regular as well as axis labels, and only works if you use TeX_strings, which we recommend anyway.

See (undefined) [Notation], page (undefined) if you want to control the use of floating point or exponential notation, and some details on how to draw exponents. If you want more control over your axis labels, see (undefined) [Axis], page (undefined).

Syntax: Break

Exit the current WHILE (see (undefined) [While], page (undefined)) loop, and continue executing commands after it.

You cannot use BREAK to escape from a DO loop; either embed the loop in a macro and use RETURN to exit early, or rewrite the DO as a WHILE loop.

Syntax: CHDIR WORD

Set the current directory to be WORD, where WORD is any valid directory. It might be wise to enclose it in quotes, e.g. CHDIR "[-more_data]", or use the cd macro. The new directory only
affects SM, for example DATA or SAVE commands. When you exit SM, you will be back where you started. If the directory starts with a ‘~’, the ‘~’ will be replaced by the name of your home directory. This is the only place that ‘~’ is significant; in particular it will not be recognised by the DATA command.¹

Your current directory is always available as the $cwd variable.

Syntax: CONNECT WORD1 WORD2 [ IF (expr) ]

CONNECT draws line segments connecting the points in vectors WORD1 and WORD2. If the IF clause is present, only connect those points for which expr (see the section on vector arithmetic) is non-zero. Only contiguous points in the input vectors will be connected, resulting in a number of line-segments. If you don’t want this behaviour, say something like

```
set l = (z==1) ? 1 : 0 set x=xx if(l) set yy=y if(l) connect xx yy
```

In fact, either or both of the WORDs may be replaced by ‘parenthesised expressions’, i.e. expressions in parentheses. For example,

```
CONNECT x (2*y)
```

plots x against 2y.

If WORD1 and WORD2 have different dimensions CONNECT will ignore the excess points in the longer vector. If you want to plot a constant value you’ll have to explicitly promote it, for example

```
CONNECT x (1+0*x)
```

which makes a rather boring plot.

To draw a line in a label you can either use CONNECT or DRAW, or use the \textTeX-macro \texttt{\textbackslash line} to directly insert your line.

Syntax: CONTOUR

Makes a contour plot of an image read by the IMAGE command (see \texttt{\textbackslash undefined} [Image], page \texttt{\textbackslash undefined}). The contour levels are set using LEVELS; plot coordinates are taken to be those set by the LIMITS command, and contours are drawn in the current LTYPE. It is not possible to produce labeled contours.

Any pixels whose value is NaN are ignored, as are any whose value equals the SM variable \texttt{$missing\_data$}; by default this is some very large number (usually 1e37). If a contour line runs into a missing data point it simply stops, rather than being made to join up with some other line that also runs into a missing point.

¹ Due to a VMS RTL bug, this command is not available on all VMS systems.
See also DITHER for dithering images, IMAGE CURSOR for using cursors to get values from images, MINMAX for finding the minimum and maximum of images, and Arithmetic for extracting cross-sections of images.

Syntax: CTYPE WORD
        CTYPE INTEGER
        CTYPE = expr

With WORD, set the line colour to be WORD, if your display device supports coloured lines, where WORD must be one of default, white, black, red, green, blue, cyan, magenta, or yellow. The colours are those composed of three, zero, one, or two of the primary colours red, green, and blue. When a device is opened it sets default to some device specific value (e.g. white for xwindows, black for sunwindows).

Initially, CTYPE INTEGER is another way of selecting the same colours as are available with CTYPE WORD, where CTYPE 1 is the equivalent of the first colour listed above, or white (so default is 0). However, the CTYPE = expr command redefines the available colours to be the elements of the array given by expr. If it is arithmetic, each element of is interpreted as RED + 256*GREEN + 256^2*BLUE for the given colour, where 0 is off, and 255 corresponds to full intensity. If the expr is string-valued it specifies the names to be used for the colours that you have just defined. Any connection between the names and colours is, of course, up to you. You can get the current value of CTYPE with DEFINE ctype 1, and vectors of the current ctypes and their names as CTYPE() and CTYPE(STRING).

So another way to get white lines would be to say:

    CTYPE = { 0 255 0 } + 256*({ 0 255 255 } + 256*{0 255 0 })
    CTYPE 1

while

    CTYPE 2

would give green lines.

    CTYPE ={ black white green }

would make your colour names correspond to reality again. You can use any names you like, you are certainly not restricted to the initial set.

You can reset the colours to their default (i.e. correct) values using the macro reset_ctype.

If you want to add a new colour you can say:

    CTYPE = CTYPE() concat 200 + 256*(100 + 256*100)
    CTYPE = CTYPE(STRING) concat 'pink'

and delete one with

    CTYPE
foreach f {"" string} {
    set ct=ctype($f) if(ctype(string) != 'pink') ctype = ct
}

(see also macros add_ctype and del_ctype).

Many devices (e.g. sunview) require you to specify a number of colours that is a power of 2, so asking for 70 colours will use up 128 slots. It is probably a good idea to use as few colours as possible, as they are scarce resources on most displays. You should also be aware that the display may use some of ‘your’ slots for the background, so specifying 63 colours on (e.g.) a sun actually requires 64 (and asking for 64 will use up 128). If you specify more colours than are physically available, or more than the device driver thinks that you deserve, SM will interpolate your values of CTYPEx for you.

If you are using X11 (see [XWindows], page [XWindows]), you will probably need to use the -cmap flag when opening your device if you want to allocate many private colours.

The default colour is specified in the device drivers, or in the DC (Default Colour) graphcap capability, and is set whenever a device is opened, so don’t try to modify it with a CTYPIX = expr command. You can, however, override the default colour with a foreground entry in your ‘.sm’ file; it should be the name of a colour (as listed above). You may also be able to specify a background colour (as background). This is either a colour name or a set of three integers in the range 0-255 specifying the red, green, and blue values. We allow you this chance to specify arbitrary colours because it’s your only chance to affect the background, and you can’t use a CTYPIX = command to compose your own palette. On some devices the name of the background colour may be chosen from a wider selection; for example if you are using Xwindows you may use any name from the colour database.

Syntax: CURSOR
CURSOR WORD1 WORD2
CURSOR READ

Display the cross-hair cursor to enable you to get positions (in user coordinates). The current cursor position is typed on the screen every time that you hit a key; some keys are special, specifically you can exit the cursor routine by hitting ‘e’ or ‘q’. If you exit with ‘e’, CURSOR issues a relocate command to set the current plot position to the cursor position, and puts the command in the history buffer. If you exit with ‘q’, no entry is made in the buffer (but the current position is still updated). Usually successive positions overwrite each other, but if a digit is used to mark a point then the position is followed by a newline, so the next time you hit a key its position will appear on the next line. (You can remember that digits lead to numerous values appearing). If the verbosity (see [Verbose], page [Verbose]) is one or more, a message will be printed reminding you what keys to use.

CURSOR
If you simply want to read the current position of the cursor, you can say CURSOR READ; this is mostly useful within macros (see, for example, animate in the macro ‘3d’).

Many graphics devices have things called “GIN terminators”. SM usually expects that this be set to ‘Carriage Return’ with no extra characters, EOT is a popular (unacceptable) choice. If you have trouble check your graphics setup screen, then with your SM Guru who can look up in graphcap to see what is expected. If the local Guru were very friendly, he could change your GIN terminator to anything he wanted, even EOT, but he probably isn’t.

The second form enables you to define a pair of vectors WORD1 and WORD2. SM provides you with a cursor, and every time that you hit a key it prints its position (just as above). If the letter is ‘e’ it draws a point of the current type at the current position, prints the current position, and enters the (x,y) coordinates in the vectors; if you use ‘m’ to mark a point the coordinates are not written to the screen, but the point is still added to the vectors. ‘p’ defines the current point, and exits. Exit without defining another point with ‘q’, so the sequence ‘e’ ‘q’ is equivalent to ‘p’. You can also abort with a CONTROL-C in which case WORD1 and WORD2 are unchanged.

Note that if you want to use SPLINE on the vectors produced in this way, you should take care that at least one of the vectors is monotonic and increasing, or use the SORT command.

See also IMAGE CURSOR which returns the value under the cursor as well as the position if an IMAGE (see (undefined) [Image], page (undefined)) has been defined.

For devices with mice, if the buttons do anything, they should generate the characters ‘e’, ‘p’, and ‘q’ (starting at the left).

The SunWindows cursor is slightly different. The cursor position is given by a pointing finger (it’s the best we could do), and SM won’t see any characters typed at the keyboard until you hit a carriage return. Device sunwindows is obsolete anyway, you should simply switch to using the sunview driver. Its cursor has a bug, in that it only sees every other character typed at the keyboard. If I knew why I’d fix it.

Syntax: DATA file

Use file file as the source of data read with the READ command. The file is assumed to have numerical data in columns separated by spaces, or tabs. The range of lines specified by LINES is reset. If the file can’t be opened for read, you will be warned. The variable $data_file is set to file. See the READ command to see how to read the data. You may need to quote the filename, e.g. DATA "/usr/file", which you can do by using the macro da: da /usr/file.

Perverse people who wish to use filenames such as ‘12’ or ‘3.14’ will find that they get syntax errors. If they must persist DATA "3.14 " will work.

DEFINE
All of these varieties of DEFINE define variable name to have some value, but as variables can be defined in all sorts of ways there are a good many possibilities. With the prefix LOCAL (which is allowed in front of any of the DEFINE commands), the variable will be local to the macro; (see (undefined) [Local], page (undefined)).

Name is a single word starting with a letter, and containing only letters, digits, or ``, and may be a keyword. Whenever SM comes across $name, it is interpreted as a reference to variable name and $name is replaced by its value. (Note that some variables such as date are special as they always contain an up-to-date value, for an example try echo $date sometime. These variables are listed under DEFINE name |.) You can also evaluate expressions with $(expr), for example echo $(pi/2). The value can’t be longer than about 80 characters, except for the value_list form in which case its length can be essentially infinite.

If you just want to know if a variable is defined, then $?name is defined to have the value 1 if name is defined, and 0 otherwise. Variables are not usually expanded within double quotes or {}, but if you use the syntax $!name the variable will be expanded within double quotes; $!!name will be expanded anywhere.

For the variants of DEFINE name value and DEFINE name value_list, value is either a word or number, or a list. The difference between using {} and <> to delimit a list is that keywords can appear within {}, but variables are not usually expanded.

With the optional [ INTEGER, INTEGER ] clause (I apologise for the notation in the manual; those [] are required) you can choose a subrange, just as SUBSTR (see (undefined) [Strings], page (undefined)) can choose a part of a vector element. For example,

```
define s <"/abc/def">[1,-2] echo $s
```

prints

```
abc/d
```

define
Why is this useful? Because it provides a way of working around limits on lengths of vector elements; otherwise this example is equivalent to

```plaintext
define s (substr('/abc/def', 1,-2)) echo $s
```

**DEFINE name DELETE**, deletes a variable (see also the macro undef to undefine variables).

**DEFINE name LOCAL**, which is only allowed within macros, creates a variable which will only be visible from the current macro, and from macros called by it (see (undefined) [Local], page (undefined)). Such local variables are automatically destroyed when leaving the macro within which they were created, and may not be explicitly deleted. This is similar to the behaviour of numbered variables, except that they really are local (i.e. they are only visible in the macro, and not in its descendents; SM's LOCAL variables have nested scope rather than being truly local).

An alternative is to prefix the DEFINE command itself with LOCAL; `DEFINE me LOCAL DEFINE me RHL` is exactly equivalent to `LOCAL DEFINE me RHL`.

A common use for DEFINE LOCAL is:

```plaintext
define i local
foreach i { sorbus aucuparia } { set $i local }
```
to protect a FOREACH (or DO) variable, and all local vectors, in one simple line. It is because such loop variables are automatically destroyed that attempts to delete local variables are not reported at VERBOSE levels of 1 or less.

**DEFINE name ( expr )** defines a variable to have the value of a (scalar) expression. When possible, it is more efficient to use vectors to perform calculations on scalars, rather than putting them into variables. It is also more efficient (and more obscure!) to use numbered variables (macro arguments) than real named ones. As a special dispensation, the expression can be an element of a string-valued vector (elements of arithmetic vectors are allowed too of course).

**DEFINE name :** defines the variable name from the environment file. If name can't be found, and is capitalised, SM will look for it in the environment (as a logical variable for VMS users).

**DEFINE name |** is used to define a variable from an internal SM variable such as `expand` or `angle`. These variables can be listed with `LIST DEFINE |` (or by `LIST DEFINE` if `VERBOSE` is two or more); a possibly incomplete list is: `angle, aspect, ctype, cwd, date, exit_status, expand, fx1, fx2, fy1, fy2, gx1, gx2, gy1, gy2, ltype, ltype_expand, lweight, nx, ny, ptype, sdepth, sheight, slength, distance, theta, phi, uxp, uyp, verbose, xp, and yp`. The current plot limits are `fx1` etc., (or `gx1` etc. in device coordinates), the size of the screen (in pixels, or dots, or whatever the hardware uses) is `nx * ny`, the current position (in user coordinates) is `(uxp,uyp)` , the current position (in plot coordinates) is `(xp,yp)`, `exit_status` is the return code from the last `!` command, `sdepth, sheight, and slength` are the depth, height, and length of the last string drawn to the screen, `distance, theta, and phi` are the viewpoint for surface plots (see (undefined) [Viewpoint], page (undefined)), and the rest should be obvious. In the case of `angle, expand, and ptype`, if

```plaintext
DEFINE
```
you used a vector to set (e.g.) the expansion, the value given will be that of its first element, and there’s also an extra value giving its dimension. This allows you to say things like

if(dimen(<$angle>) == 2) { echo You used a vector angle command }

This sort of variable changed a little with version 2.1.1. The variables that you can use have not changed, but their usage has slightly. They are all defined for you when SM starts and each is always correct, tracking the current value of the corresponding internal variable. For example, try echo $angle\n angle 45 echo $angle. If you now say define angle 1, $angle will cease to track the internal value and will remain fixed (the same effect can be achieved with define angle 45). When you say define angle delete it will once more track the internal value. Your old code will continue to work, but in many cases it is possible to remove the explicit definition with |. This special sort of variable will not be SAVED, and will not show up if you list the currently defined variables (unless VERBOSE is two or more).

DEFINE name ? will prompt you for the value of name at the keyboard, using the prompt string if given, otherwise the name of the variable. The old value of the variable (if defined) is printed within [], and is taken to be the default if you simply hit carriage return. As previously discussed, the difference between {} and <> is in the treatment of keywords and variables. If you don’t want to use {} (probably because of something weird to do with when variables are expanded), you can always use quotes within <>. The versions of the DEFINE command including READ define variables from the current data file. DEFINE name READ INTEGER sets name to be line INTEGER of the current data file, while DEFINE name READ INTEGER INTEGER2 defines name to be word INTEGER2 of line INTEGER. name is subject to the usual restrictions. If the line begins with a # the first character is simply ignored when defining variables.

DEFINE name IMAGE defines a variable from a file read with the IMAGE or TABLE command. Currently this only works for NX, NY, X0, X1, Y0, Y1, or any keyword from a FITS header. Any minus signs (−) appearing in name are converted to underscores (_), as SM doesn’t allow − in a variable name.

You can define further such variables using IMAGE DEFINE name value, a facility that is chiefly useful in connection with the WRITE IMAGE command (see (undefined) [Image], page (undefined)).

LIST DEFINE lists all currently defined variables, or all those which are between begin and end alphabetically (asciily). Examples

DEFINE v1 5.993
DEFINE label1 KPNO
DEFINE label1 < National Optical Astronomical Observatory >
DEFINE v2 ($v1 + 3.4)
DEFINE v1 DELETE
DEFINE age ? { How old are you? }
DEFINE macros : WRITE STANDARD "$!macros"

(Note that we couldn’t have used <> to prompt for your age, because then the ? after you would be treated as a keyword).

To illustrate the DEFINE name READ commands, consider a file with the following lines:

This is a file containing astronomical data
Magnitude Intensity Wavelength Error

Then using the DEFINE commands as follows:

DEFINE title READ 1
DEFINE labelx READ 2 3

will assign the string This is a file containing astronomical data to the variable title, and the word Wavelength to the variable labelx, so you can say XLABEL $labelx.

Syntax: DELETE [ INTEGER1 [ INTEGER2 ] ]
DELETE HISTORY [ ! ]
DELETE HISTORY [ INTEGER1 [ INTEGER2 ] ]
DELETE WORD

Delete commands INTEGER1 to INTEGER2 (inclusive) from the history buffer. If the INTEGERs are not present, delete the last command. DELETE 0 will delete all history commands. If the INTEGERs are negative they are interpreted relative to the current command, so -1 is the last command.

The DELETE HISTORY commands are identical to the DELETE commands, except they themselves do appear on the history list; they are preserved for backwards compatibility and because DELETE HISTORY \n can be used to prevent a command from appearing on the history list (the macro dell). If a macro contains a DELETE HISTORY, or calls a macro that contains one, or ... the macro will not appear on the history list. Traditionally, this meant that if there were two (or more) occurrences of DELETE HISTORY the previous command(s) were also be deleted, but in SM version 2.2.1 this has been changed, and DELETE HISTORY will only delete the last command typed at the keyboard. If for some nefarious purpose you really do want to delete older commands too, you can say DELETE HISTORY ! and the command will work the old way.

DELETE WORD deletes the vector WORD (see SET WORD or READ WORD for how to define vectors), MACRO name DELETE is used to delete a macro, DEFINE name DELETE deletes a variable.

Syntax: DEVICE WORD [ rest_of_line ]
DEVICE INTEGER [ WORD ] [ rest_of_line ]
DEVICE META WORD
DEVICE META CLOSE

DEVICE
Choose a device to plot to. Exactly which devices are available depends on your hardware configuration and how SM was compiled. You can list available devices with the LIST DEVICE command (see (undefined) [List], page (undefined)). When you specify a device the previous device is closed, which may lead to some action being taken (for example, sending a plot to a printer).

When a device is opened it is looked up by name in the `graphcap' file (see (undefined) [Graphcap], page (undefined)). In some cases all the information that SM needs to plot to the device is available there (for example xterm or postscript); such devices are referred to as stdgraph devices. Otherwise the graphcap entry will contain the name of the real device driver, for example x11. Anything else on the line is passed to the device driver. In particular, for the stdgraph devices an argument that is not specifically processed by the device is taken to be the name of a file to save the plot in. Thus \texttt{device postscript foo.ps} creates a plot in a file called `foo.ps'.

The pseudo-device META is special (see (undefined) [Meta], page (undefined)). It is used to support metafiles, which allow you to save a plot as you display it, and finally send it to a different device.

Especially for hardcopy devices, you may have to specify which one you want, e.g. \texttt{DEVICE postscript latentus}. Because this depends on how your local graphcap was configured, you'll have to see your Guru for guidance; see (undefined) [Graphcap], page (undefined).

When a device is opened, it is set to the current CTYPE, LWEIGHT, and LTYPE, and the proper aspect ratio is chosen to make text and plotted points look nice. It also looks for an entry \texttt{foreground} in your `.sm' file, and uses it as the default colour for the device (this overrides any default that the device driver may have specified). The device driver may (or may not) choose to honour a \texttt{background} entry as well. These colours may be specified either as names (see CTYPE), or the background colour may be given as a set of three numbers, which are interpreted as the red, green, and blue intensities in the range 0 - 255. Some devices may allow you a wider selection of background names; for example the Xwindows driver allows any name from the colour database.

If you want to use some foreground colour that CTYPE doesn't usually understand you must define it before opening the device. For example, after defining the macro

\begin{verbatim}
add_colour 4 ## add a colour to the standard set. Usage: name r g b
      CTYPE=<0 255 0 255 0 0 0 255 255 $2> + \ 
      256*(<0 255 0 0 255 0 255 255 0 255 $3> + \ 
      256*<0 255 0 0 0 255 255 0 255 0 $4>)
      ctype=<default white black red green blue cyan magenta yellow $1>
\end{verbatim}

\footnote{This isn't actually the preferred way to create a postscript file; it's better to use a specialised device such as \texttt{postfile} (see (undefined) [Postscript], page (undefined)), or at least to say \texttt{device postscript ":SY=mv $F foo.ps:"} (see (undefined) [Stdgraph], page (undefined)).

\texttt{DEVICE}
you could say `add_colour gray 200 200 200', after which `gray' would be a perfectly good `fore-
ground' colour.

Different ways of plotting to the same device (e.g. portrait or landscape) are accommodated
by using different drivers (e.g. `postport' and `postland' for postscript devices) rather than some
magic command to SM.

The NULL device

DEVICE `nodevice' is always available; it is a bit bucket where plot commands may be sent
never to be seen again, the equivalent of `/dev/null' (under unix) or `n1'; under VMS.

It is useful because it is always available; it's the current device when SM is started. Because
SM submits plots only when the current device is closed, and because opening `nodevice' closes the
current device, it is also used by the hardcopy command (in fact `hardcopy' is a macro that expands
to DEVICE `nodevice').

Borland Graphics on a PC

SM works on a PC running DOS either by using Borland's graphics or windows (see the section
on MS-Windows); this section describes the former. SM was ported to run under DOS by Laurent
Bartholdi, who also wrote the BGI and MS-Windows device drivers. He gets all the credit for the
PC version of SM, but of course he is not responsible for any remaining bugs (some of which we
almost certainly created while merging the PC and regular versions).

The graphics drivers, the `.bgi' files, are assumed to be in a directory given by the DOS
BGIPATH environment variable; alternatively you can specify a bgipath variable in your `.sm'
file.

The DEVICE command takes two optional arguments: DEVICE `bgi devtype mode'. The first,
devtype, is the type of hardware that you are running. If you want the driver to try to figure this
out for itself, use DEVICE `bgi detect' (this is the default if you omit devtype entirely); for a listing of
possibilities say DEVICE `bgi ?'. The second argument, mode, determines how SM switches between
screen and graphics modes. Your options are `none', `swap' (the default), or `switch'; experiment to
see which works better for you. At present, a certain amount of `snow' is left at the top of the
graphics screen. This is very dependent on the details of your graphics card, and we see no general
way to prevent its appearance.

Once you have decided what options you like best, you can set a variable stdmode in your `.sm'
file (e.g. to detect `swap') to save yourself some typing.

There is a `hot key', ALT-F1, that can be used to toggle between text and graphics mode.

The current return value of the function `coreleft' is available as `$coreleft' (which is like any
other DEFINE var | variable).

OS/2 Presentation Manager

DEVICE
The OS2PM driver is used to display graphics in a Presentation Manager graphics window under OS/2 v2.x (you should specify your terminal as os2pc). Two optional arguments are currently supported:

-n Disable all backing for the graphics window. This will significantly increase the drawing speed, but the contents of the graphics window will not be redrawn when portions of the window are uncovered or when the window is resized.

-gWxH Specify the window geometry. The W and H parameters should contain the WIDTH and HEIGHT of the graphics window in pixels.

If DEVICE os2pm is specified without the -gWxH argument the graphics window will be created the same size as the last previously displayed window. If this is the first time the graphics window is created it will default to 600 x 400 pixels.

For example,

```bash
DEVICE os2pm -g800x500
```

The first DEVICE statement will produce an 800 x 500 pixel graphics window with backing enabled. The second will again produce an 800 x 500 pixel window but with no backing.

Graphics Metafiles

As described elsewhere (see [Meta], page [undefined]) SM can save graphics commands to a metafile while producing a plot on your screen.

Postscript Devices

Strictly speaking, there are no postscript devices, merely postscript drivers in stdgraph (see [Graphcap], page [undefined]). On the other hand, SM is able to drive postscript printers in a totally transparent way, so a user can think of SM’s postscript capability as discrete drivers. In the following descriptions the arguments to the device command are referred to as $1, $2, and so on. Aliases are listed in parentheses after the device name, so post_colour can also be called post_color. Those currently supported are:

- **postscript (POSTSCRIPT)**
  The basic driver; produces 8x8inch output on the default printer.

- **postport (POSTPORT)**
  A full-page portrait-mode plot.

- **postland (POSTLAND)**
  A full-page landscape-mode plot.
post_colour (post_color)
   Like postscript, but generates a colour postscript plot, and sends it to a printer called
   ps_colour0.

blackpostscript
   Like post_colour, but uses a black background.

postfile (postencap)
   Like postscript, but generate an encapsulated postscript file in $1.

postlandfile
   Like postland, but generate an encapsulated postscript file in $1.

post_remote (postscript_remote)
   Like postscript, but prints to a printer $2 on host $1.

postland_remote
   Like postscript, but prints to a printer $2 on host $1.

postport_remote
   Like postport, but prints to a printer $2 on host $1.

For an example of defining your own postscript device that takes a printer name as an argument,
see (undefined) [Graphcap], page (undefined).

The Silicon Graphics (and RS-6000) Device

The Silicon Graphics device driver works. If you read this and want more documentation, send
mail to us and we’ll get to it.

The General Device Driver, using Graphcap

By far the majority of devices that SM supports are driven through the stdgraph device; a
partial list includes tek4010, tek4012, pericom, selanar, (or hirez ), versaterm (or macvt ),
vt640 (a vt100 with retrographics ), vt240 in REGIS mode, hard4012 or hard4010 for a tek4010
that really has no decent ascii mode, tek4025, wyse1575, cit414a or 414a. We also support
graphcap drivers for Postscript, QMS, and LN03 laser printers, (device names postscript, qms
and ln03). Stdgraph can also cooperate with raster devices, for instance to plot on a lineprinter.

For the stdgraph (i.e. default) device driver the final word on the command line (if present) is
taken to be the name of a file to receive the output that would ordinarily go to the screen, so if
you say

   device graphon outfile

and then create a plot nothing will seem to happen. However, if you close the device and write
‘outfile’ to the terminal (maybe using /passall if you are running VMS) your plot will appear.
In addition, any word beginning with a colon will be taken to be part of a graphcap entry (see
(undefined) [Graphcap], page (undefined)), and prepended to the entry in the graphcap file for your chosen device. For example, if you wanted to save your postscript output in a file you could say

```
dev postscript ":SY=echo File is $F:
```

which would replace the SY entry that sent the output to the printer by a new one that merely tells you what the file is called. If you’d prefer to give it a memorable name, you could say

```
dev postscript ":SY=echo File is \$F:OF=name:
```

or

```
dev postscript :SY@: :OF@: name
```

(it doesn’t matter if the entries are all in the same word). The former redefines the output file OF to be “name”, and makes SY tell you so. The latter disables both OF and SY, so the generated postscript would ordinarily go to the terminal (just like any other graphics terminal), but a file ‘name’ is specified, so the output is sent there instead.

If you find yourself frequently wanting to use a customised stdgraph device, this mechanism can become rather tedious; you’d rather simply invent the device and be done with it. The proper way to do this is to create a local graphcap file (see (undefined) [Graphcap File], page (undefined)), and add your new device to it. For example, if you wanted to define a postscript device that took the name of the printer as its argument, you’d put an entry

```
mypostscript\like postscript, but specify the printer as its argument:\
:SY=\lpr -r -P$1 $F;TC=postscript:
```

in your file, and merrily proceed with making beautiful plots using `DEVICE mypostscript fred`. If you always want to use your new device you could call it `postscript` and in effect redefine the old `postscript` device (note carefully that I said :TC=postscript: not :tc=postscript:; if I hadn’t, an infinite loop would have resulted).

**The SunView (and Sunwindows) Devices**

As the `sunwindows` driver is now obsolete, and may well disappear in some future release, you should use the `sunview` driver instead. If you insist on using the old driver, it must be run from within a gfxtool.

The SunView window driver supports a subset of the usual SunView command line arguments, specifically:

- `-WH` Summarise options
- `-Wi` Open window as an icon
- `-Wl label` Specify label for the window (default: SM)
- `-Wh` Don’t label window

DEIICE
The standard SunView popup ‘frame’ menu has been modified to allow you to erase the graphics screen. It is perfectly safe to use the menu to quit the graphics window, in this case the next device sunview command will create a new one. If SM thinks that the window is active when you try to kill it, it will warn you; failing to believe it may result in a cascade of complaints to the console window. There is a bug in the cursor routine (I claim that it is a SunView bug) that means that SM sees only every other key-stroke.

A Tcl/Tk Widget

It’s possible to build SM to support a Tk widget (on unix boxes only; the SM Tk graphics are based on X11). If this interests you, specify the Tk device when building SM, then build tkSM in the callable directory and say

\texttt{tkSM smtk.tcl}

to run an example that we wrote. The source code should be easily modifiable to add features that your application needs.

The Unix-PC Device

On a Unix-PC \texttt{DEVICE upc} opens a window of 304 by 192 pixels, which is about 4 by 4 inches. To quote the author (Peter Teuben, teuben@astro.umd.edu),

1. This whole Unixpc version is an experimental version, take it as is, it works on my configuration, but may not work on yours.
2. I’m playing with allowing a second and third parameter to the upc device name, which would allow you to change the default size of 304 by 192 pixels (The size in X must be a multiple of 16 though). Right now I have it check environment variables \texttt{YAPP_X} and \texttt{YAPP_Y}, but this may not work satisfactorily.
3. I spawn windows using the public domain program ‘wlogin’, this may be of some importance if your ‘upc’ device in SM fails.

I don’t have a Unix PC, so I can’t work on this driver.

PC Graphics under MS-Windows

This section needs more work; send mail to \texttt{rhl@astro.princeton.edu}.

\texttt{VAX/VMS UIS$ device

VAX/VMS UIS$ device
the VAXUIS driver is used to display graphics on a VAX Workstation using the VAX UIS$ library routines. The optional X and Y parameters specify the size of the graphics window (in centimeters) created on the workstation screen.

If called without the optional X and Y parameters the graphics display window will be the same size as that previously displayed.

If the X and Y parameters are not specified the first time the DEVICE vaxuis command is issued, the graphics display window will occupy 1/2 the height and 1/2 the width of the workstation screen.

For example, to create a 15 cm wide x 10 cm tall display window say:

```
DEVICE vaxuis 15 10
```

The X-Windows Devices (X10 and X11)

There are two X-Windows drivers, one for X10 and one for X11 and they differ in their treatment of command line arguments. The X11 driver is considerably more sophisticated and will be treated first.

The X11 window driver (device x11) supports a subset of the standard command line arguments, specifically (the X-resources names appear in parentheses at the ends of the descriptions):

- **#geom** Specify icon geometry (.icongeometry)
- **-bd n** Border width (.borderwidth)
- **-bg colour** Background colour (.background)
- **-device n (.device)** Use X11-device n
- **-cmap** Use a private colour map for this device (.colormap)
- **-colormap** Use a private colour map for this device (same as -cmap). (.colormap)
- **-colourmap** Use a private colour map for this device (same as -cmap). (.colormap)
- **-cmap** Use a private colour map for this device (.colormap)
- **-display name** Name of display to open (.display)
- **-fg colour** Foreground colour (.foreground)
- **-fn fontname** Name of hardware font to use (.font)
-geometry geom
   Specify window geometry (.geometry)

-help
   Summarise options

-kbdfocus
   Preserve keyboard focus (the same as -focus). Without this, some window managers
   transfer focus to the graphics window when it is created; probably not what you want
   (.kbdfocus)

-icn
   Open window as an icon (.icn)

-name name

-ndevice n (.ndevice)
   Allow up to n X11 devices

-nocurswind
   Do not show the cursor position while in cursor mode (same as -nocw) Specify name
   of window (.name)

-preopened display_id:window_id
   Specify device and window id's

-synchronise
   Synchronise with server (debugging only) (.synchronise)

-title title
   Specify title of window (.title)

Where geom is a standard geometry string of the form WxH+-X+-Y, and the preopened option is
for a programme calling SM non-interactively. All options may be abbreviated, so

device x11 -i #1+1 -g 512x512+100+100

specifies that the graphics window be created as an icon in the top right hand corner of the screen,
and that the real window should be 512*512 and positioned near the top left corner.

SM is able to open more than one x11 device (by default it can handle 5); see the -device and
-ndevice options. You can say device x11 -dev + to switch to the next open X11 device; device
x11 -dev - switches to the previous one.

If you want to raise your graphics window so that you can see it, you can either use the window
manager, reopen the device (dev x11), erase the screen, or use the PAGE command.

On hardware that doesn’t support a backing store (or if you have chosen to disable a backing
store when compiling the X11 driver) the screen will only be refreshed when it is active or when
SM is waiting for input. If your operating system doesn’t support the select() system call you
may be even worse off, but reopening the device (device x11) should still result in the screen being
redrawn.
If you use \texttt{CTYPE = expr} to ask for more than a small number of special colours (see \texttt{undefined} \cite{ctype}, page \texttt{undefined}), you will probably need to specify \texttt{-cmap} to get your own colour map; if you don't SM may well complain about being unable to allocate colours.

The X10 driver is known as \texttt{xwindow}, and you can optionally specify a device to open, and a window ID, on the command line. For example

\begin{verbatim}
device xwindows DEVICE unix:0
\end{verbatim}

will open a graphics window on device \texttt{unix:0}. (You can optionally include a \texttt{ID number} after the \texttt{DEVICE} if you are calling SM from a programme, and have already opened the window). The X10 driver doesn't bother to remember any hardware characters that you may have written on a graph, so that if you refresh the window they won't appear. If this worries you can, as always, force the software character set with an \texttt{expand 1.001}.

\begin{verbatim}
Syntax: DITHER x y min max fac
\end{verbatim}

Generates a dithered representation of an image read by the \texttt{IMAGE} command (see \texttt{undefined} \cite{image}, page \texttt{undefined}). The vectors \texttt{x} and \texttt{y} are set to points whose density is proportional to the image's intensity (only values between \texttt{min} and \texttt{max} are considered).

Any pixels whose value is \texttt{NaN} are ignored, as are any whose value equals the SM variable \texttt{$missing_data}; by default this is some very large number.

The dithering algorithm used is Floyd-Steinberg, and each pixel of the image is represented by (up to) \texttt{fac*fac} points, where (of course) all \texttt{fac*fac} points are only used for intensities greater than equal to \texttt{max}. Even the case \texttt{fac == 1} can produce nice output for suitably sampled images.

The resulting vectors are usually plotted as \texttt{ptype 1 1}.

An example of dithering an image would be:

\begin{verbatim}
IMAGE image_file
DITHER x y 0 3000 4
PTYPE 1 1
POINTS x y
\end{verbatim}

Of course, you can be more sophisticated; for example:

\begin{verbatim}
define min 3000  define max 60000  define gamma 2
set ii = image[*,*]  
set ii=(ii < $min ? 0 : ii > $max ? 1 : (ii-$min)/($max - $min)
set image[*,*] = (1 + $gamma)*ii/(1 + $gamma*ii)
dither x y 0 1 4
define v local foreach v (x y) {
    set $v=$v + 0.5*random(dimen($v))
}
POINTS x y
\end{verbatim}

DITHER
or

\begin{verbatim}
DITHER x y 0 3000 1
expand 0.3 + IMAGE(x,y)/3000
PTYPE 4 3
POINTS x y
\end{verbatim}

See also IMAGE for reading images, CONTOUR for contouring them, IMAGE CURSOR for using cursors to get values from images, MINMAX for finding the minimum and maximum of images, and Arithmetic for extracting cross-sections of images.

Syntax: DO variable = start, end [ , incr ] { commands }

While the value of $variable$ runs from start to end, the commands are executed. The optional increment defaults to 1. It is not possible to change the value of the loop variable inside a loop (or at least it has no effect on the next iteration). To break out of a loop you have to break out of the current macro as well with RETURN (see (undefined) [Loops and If], page (undefined)).

For example,

\begin{verbatim}
DO i=1,10,0.5 { WRITE STANDARD $i }
\end{verbatim}

will write 1 1.5 2 2.5 ... 10 to the terminal. The commands may be spread over several lines.

Syntax: DOT

Draw a point at the current location (set by RELOCATE, DRAW, etc.) in the style determined by PTYPE. The point’s size and rotation are governed by EXPAND and ANGLE.

To insert dots into labels, it may be easier to use the ‘\LaTeX’ definition \point or \apoint which inserts a dot of a specified PTYPE into a string (see (undefined) [Fonts], page (undefined)).

Syntax: DRAW #1 #2

\begin{verbatim}
DRAW ( #1 #2 )
\end{verbatim}

Draw a line from the current position (set with, for example RELOCATE) to (#1, #2) in user coordinates. If the parentheses are present, use screen coordinates.

Syntax: EDIT function key_strokes

Bind a function to a set of key_strokes for the editor. For example, EDIT refresh CONTROL-R makes the CONTROL-R key refresh the screen. A complete list of functions is given in the ‘Changing Key-Bindings’ section in the main part of this manual (see under ‘bindings’ in the index). Each character in the key sequence can be specified as a character, e.g. ‘a’ or the single character
‘CONTROL-A’, as ‘CONTROL-C’ representing the single character CONTROL-C as the two character sequence ‘^’ followed by ‘c’, or by ‘\nnn’ where nnn is an octal number (e.g. EDIT refresh \022).

In order to use multiple key sequences (e.g. CONTROL-ACONTROL-BCONTROL-C) you must first undefine any sub-sequences, in this case CONTROL-A and CONTROL-ACONTROL-B, by making them illegal – EDIT illegal CONTROL-A.

See READ for how to define a set of keys from a file, and KEY for how to define keys to execute commands.

---

**Environment (‘sm’) Variables**

SM environment variables are defined in ‘.sm’ files, which are searched for along a path which typically consists of the current directory, your home directory, and then some system place. You can specify your own search path by setting the environment (VMS: logical) variable SMPATH. If ~ appears in a path it is interpreted as your home directory unless you specified -u NAME when starting SM, in which case it will be interpreted as NAME’s home directory instead. Alternatively, you can specify the name of the environment file using the `-f` flag on the command line; if it starts with a ‘/’ it will be taken to be an absolute path name, otherwise it will be taken relative to the current path.

If you invoke SM with the -f or -u flags, the are not passed on to raster devices, so if you plot to a device that invokes rasterise it will use the .sm files specified by $SMPATH.

Each line of the files is taken to consist of a variable name, and the rest of the line which is taken to be its value. Any variable may be accessed using the DEFINE name : command, which defines name from the environment file.

Comments run from ‘#’ to the end of the line. If the first character of a line is a ‘@’ or ‘+’ the name is taken to start with the second character. A ‘@’ means that the entry isn’t present, and that SM should stop searching the path for it. A ‘+’ means that SM should keep on searching the current ‘.sm’ file, and then the rest of the search path, looking for more entries with the same name. If it finds one, the second value is added to the end of the first (and if the second occurrence also had a ‘+’ specified the search continues).

Some entries in the environment file are special to SM, although you are free to use them to your own ends as well. For most of those for which SM is only interested in whether the variable is defined, a value of 0 means that it shouldn’t be defined. The variables are:

- **background**
  The background colour for plots

- **case_fold_search**
  If non-zero, make searches case insensitive
default_font
The default font for labels; you can also set this interactively, e.g. expand 1.001
define default_font "\oe\3".

device
Your initial graphics device

edit
A file of keybindings to read (see (undefined) [Key Bindings], page (undefined)).

fan_compress
Apply fan compression when connecting lines. This was donated by a user, and is
intended to reduce the number of lines actually plotted to the device; whether it is
useful is not clear. The reference is IEEE Computer Graphics and Applications, March

file_type
The type of 2-D image for the IMAGE command

filecap
The filecap file to use (default: same as graphcap)

line_up_exponents
Force an extra space before single-digit exponents in axis labels

fonts
The name of the binary fonts file

foreground
The foreground colour for plots

graphcap
The graphcap file to use

help
The help directory

history
The length of the history list (default: 80)

history_char
The character used to recall commands (default: ^)

history_file
File to save history in

macro
The default macro directory

macro2
Your private macro directory

missing_macro_continue
If defined, a reference to a missing macro isn’t a syntax error

name
The name SM calls you by

noclobber
Refuse to overwrite existing files with MACRO WRITE or PRINT.

overload
If non-zero, overload some commands

printer
The default printer (see hcopy and hmacro)

ENVIRONMENT VARIABLES
prompt  The initial value of SM’s prompt
prompt2  The initial value of SM’s secondary prompt
remember_history_line  
Remember which line you last reused
save_file  
Default file to save a SM session in
save_read_ptr  
Save the position of the read pointer between READ commands
temp_dir  The directory for temporary files
term  Default terminal, over-ruling TERM
termcap  The file describing terminals to SM
TeX_strings  
Use TeX-style strings for labels
traceback  
Print the macro stack following an error
uppercase  
Define uppercase versions of some macros
x_gutter  y_gutter  Modify the spacing between windows when using the WINDOW command. (These are not actually read from the `.sm` by the default startup macro, you have to set them yourself).

Under Unix, you should omit the `termcap` entry, or point it at `'/etc/termcap'`. Also under Unix, SM knows how to look up your name, so you can omit the `name` entry. If you try to use a name with more than one word, SM will use the first so you’ll have to call yourself ‘my lord’ rather than ‘my lord’ (the ‘_’ will be replaced by a space).

Some of these are used directly by SM (e.g. `help, fonts`, but some are merely used by the `startup` macro to set the initial value of SM variables (e.g. `TeX_strings, file_type`). Other names may be used by the default `startup` macro, e.g. `macro2` to specify a private macro directory or `term` to specify the terminal that you are using. See the discussion of `startup` under ‘useful macros’.

---

**Syntax:** ERASE

ERASE erases the graphics screen. The macro `era` erases the screen without appearing on the history buffer. If you want to start a new output page on a hardcopy device use the PAGE command.

ERASE
You may be able to erase individual lines with LTYPE ERASE, if you can you should look at the macro undo.

Syntax: ERRORBAR WORD1 WORD2 expr INTEGER

ERRORBAR is analogous to POINTS; it draws one-sided error bars on all points defined by vectors WORD1 and WORD2, where the length of each error bar is set by the corresponding value in expr. INTEGER is 1 to put the bar along the +x direction, 2 for +y, 3 for -x, and 4 for -y. Use EXPAND to govern the size of the caps. In fact, instead of either or both of WORD1 and WORD2 you can use an expression in parentheses, for example ERRORBAR (lg(x)) (lg(y)) 120 1.

See also the macros ec and err for backwards compatibility with Mongo, and error_x and error_y to produce (symmetrical) two-sided errorbars. There is also a macro logerr to draw errorbars on logarithmic plots.

Syntax: EXPAND expr

EXPAND expands all characters and points, its default is 1.0. Note that the EXPAND factor is used in determining the plot window size in the WINDOW command. This means you should declare your EXPAND size to SM (if other than the default) before you use WINDOW. The current value of EXPAND is available as a DEFINE expand |

If EXPAND is set to exactly 1, and ANGLE is exactly 0, then SM will use hardware fonts, when available, in writing labels. This is faster, but if you don’t like it say “EXPAND 1.00001”, or “ANGLE 0.00001”, or use a \r explicitly to select the roman font.

EXPAND can in fact be given a vector of values, which are used for each point in a POINTS command. This supersedes the use of a fractional PTYPE (although we still support it as a quaint anachronism). Using vectors for both ANGLE and EXPAND makes it easy to draw a vector field, see (for example) the vfield macro. If more points are specified than the dimension of expr, the first element will be used for the excess.

Syntax: FFT n pexpr1 pexpr2 WORD1 WORD

Fourier transform 2 vectors (treated as the real and imaginary parts of a complex vector), returning the answer in the two vectors WORD1 and WORD2. The input vectors may be the names of vectors or expressions in parentheses. The direction is specified by n, either +1 for a forward transform, or -1 for an inverse.

The dimension of the vectors need not be a power of 2, but the transform is more efficient if it is. The worst case is when n is prime, in which case this command performs a slow Fourier transform in $O(n^2)$ time.

FOREACH
Syntax: FOREACH variable ( list ) { commands }
FOREACH variable { list } { commands }
FOREACH variable WORD { commands }

In the first two forms, the value of variable is set to each element of list in turn, and then the commands are executed. An example would be

FOREACH
var ( alpha 2 gamma ) { WRITE STANDARD $var }

which would write alpha, 2, and then gamma to the terminal (see (undefined) [Loops and If], page (undefined)).

The form with {} can be useful if you want the list exactly as you type it, for example

FOREACH f { 0.1 $date } { echo $f }

The form FOREACH variable WORD ... is used to iterate over a vector, either arithmetic or string. For example,

SET str={Sorbus Aucuparia David Monger}
FOREACH f str { echo $f }

It is often useful to define the FOREACH variable to be LOCAL (see (undefined) [Define], page (undefined)), e.g. DEFINE f LOCAL in the last example.

Syntax: FORMAT [ x-format-string y-format-string ]

Allow the user to specify the axis tick label formats. The format should be given as a standard C (e.g. %4.1g) or Fortran (e.g. F10.4). This format will be in effect until unset by issuing the FORMAT command with no argument, in which case SM will figure out the best format for you, or until you issue a new FORMAT command with new format strings.

If a format is specified as "0", the format string is left unchanged; if it is given as "1", the default value is reinstated. The command FORMAT 1 1 is thus equivalent to FORMAT.

Syntax: GRID [ INTEGER1 [ INTEGER2 ] ]

Grid draws a grid at either major ( INTEGER1 = 0 ) or minor ( INTEGER1 = 1 ) tickmarks within a box. The default is INTEGER1 = 0. You can use INTEGER2 to specify only drawing an x- or y-axis grid: if INTEGER2 is omitted or 0, draw both x and y; if it’s 1 only draw x; if it’s 2 only draw y (3 is equivalent to 0).

Syntax: HELP [ word ]

HELP
The HELP command tries to help you with word. If possible, it prints the entry from the help
directory specified in your `.sm' file, the definition of word if it’s a macro, the value of word if it’s a
variable, and the HELP string if it is a vector. If none of these are defined, HELP confesses defeat.
You might want to use the abbreviation h which will not appear on your history list (or you could
overload help itself). Further discussion of the HELP command is given in See (undefined) [Getting
Help], page (undefined).

If word is omitted it is assumed to be HELP.

You can associate a help string with a vector with the command SET HELP.

See also APROPOS and LIST.

Syntax: HISTOGRAM WORD1 WORD2 [ IF (expr) ]

HISTOGRAM connects the points in vectors WORD1 and WORD2 as a histogram. The ith bin
of the histogram is taken to run from \( (x[i-1] + x[i])/2 \) to \( (x[i] + x[i+1])/2 \); for the case of
equally spaced x-values, this reduces to saying that the x values are the bin centres.

If the IF clause is present, only use those points for which expr (see the section on vector
arithmetic) is true (i.e. non-zero). Only contiguous parts of the histogram are connected; if you
don’t want this behaviour, say something like

\[
\text{set } l = \begin{cases} 1 & \text{if } (z==1) \\ 0 & \text{otherwise} \end{cases} \text{ set } x=xx \text{ if}(l) \text{ set } yy=y \text{ if}(l) \text{ histogram } xx yy
\]

In fact, either or both of the WORDs may be replaced by ‘parenthesised expressions’, i.e. expres-
sions in parentheses. For example,

\[
\text{HISTOGRAM } x \ (2 + y)
\]

to plot x against 2 + y. There is a macro barhist for drawing bar charts. See Arithmetic for how
to convert vectors of data into histograms, and SHADE for how to shade them.

Syntax: HISTORY [ - ]

List the current commands stored in the buffer. For details on the history system, see (unde-
defined) [History Editor], page (undefined). With the optional minus sign, the history list is printed
backwards which is probably what you want if you are thinking of it as a set of commands to repeat.
It’s possible to overload list to be a synonym for HISTORY, see ‘overloading’ in the index.

Syntax: IDENTIFICATION str

IDENTIFICATION puts the current date and time followed by str outside the upper right
hand corner of the plot region. (Actually, identification is a macro, which RELOCATEs to a

IDENTIFICATION
point above the right-hand axis, and half way between the top axis and the top of the page, and then writes a string with a PUTLABEL 4.) Note that the variable $data_file is set to the name of the current data file, and $date always expands to the current date and time.

Syntax: IF ( expr ) { list }
IF ( expr ) { list } ELSE { list }

If the expr is true (non-zero), then the list of commands are executed, otherwise the ELSE clause is executed. For various complicated reasons, the ELSEless command must end with a newline (or as usual a \n) (see ⟨undefined⟩ [Loops and If], page ⟨undefined⟩). One common use for IF tests is when the expression tests if a variable has been defined, e.g.

IF($?file_name == 0) { DEFINE file_name ? }

within some macro.

Note that you can write IF-ELSE IF-ELSE blocks as

    if('Robert' == 'Patricia') {
        echo Something’s wrong
    } else { if('Patricia' == 'Ralph') {
        echo Still wrong
    } else {
        echo Go Yankees
    }
}

There are also commands using IF to define vectors conditionally (see SET), and to plot parts of vectors (See CONNECT, HISTOGRAM, POINTS).

Syntax: IMAGE [n] file
      IMAGE [n] file xmin xmax ymin ymax
      IMAGE [n] file [ * : *]
      IMAGE [n] file [ x1, x1 : *]
      IMAGE [n] file [ * : y0, y1]
      IMAGE [n] file [ x1, x1 : y0, y1]
      IMAGE ( nx , ny )
      IMAGE ( nx , ny ) xmin xmax ymin ymax
      IMAGE CURSOR
      IMAGE CURSOR WORD WORD WORD
      IMAGE DELETE
      IMAGE DEFINE variable value
      WRITE IMAGE WORD

Read an image from file, optionally specifying the range of coordinates covered by the data values. If you do not specify them they will be taken to be 0 nx-1 0 ny-1 where nx and ny are the dimensions of the image. If you specify ( nx, ny ) instead of a filename an empty image of the desired size will be created (see ⟨undefined⟩ [2-D Graphics], page ⟨undefined⟩).
If you specify \( n \) the \( n \)’th IMAGE extension of a fits file will be read; the primary data unit (i.e. the start of the file) is \( n == 0 \).

If you want to read part of an image you can specify the desired part using \([ \ldots : \ldots ]\); (n.b. those \([\ldots]\) are part of the command you type, not optional parameters). If you want the whole range use \(*\), otherwise a pair of 0-indexed integers. In other words,

\[
\text{IMAGE file}
\]
and
\[
\text{IMAGE file \[ * : * \]}
\]

are identical; you can read only the first 100 elements of the first row of an image into a vector with

\[
\text{IMAGE file \[ 0,99 : 0,0 \] SET x=IMAGE\[*,*\]}
\]

IMAGE CURSOR is identical to the CURSOR command (see (undefined) [Cursor], page (undefined)), except that value of the image under the cursor is returned in addition to the position; IMAGE CURSOR WORD WORD WORD is equivalent to CURSOR WORD WORD, but it also generates a vector of image intensities.

IMAGE DELETE will forget the current image and levels.

The file format is specified using a ‘\text{filecap}’ file, similar to ‘\text{graphcap}’, and the entry to use in this file is given by the variable \text{file_type} (see (undefined) [2-D Graphics], page (undefined)). The file is unformatted, and should start with two integers giving the dimensions of the data array, followed by the data values written row by row.

The current entries in ‘\text{filecap}’ support files written from C, or from fortran in one of a variety of ways. For C programmers, DEFINE \text{file_type C}, the file should be written with open/write/close. For Fortran, there are a variety of options depending on operating systems and the details of how the file was opened. Under Unix, simply DEFINE \text{file_type unix}. Under VMS you have a choice. You can either create a variable record type file (\text{recordtype='variable'} in the \text{OPEN} statement) and choose \text{file_type vms_var}, or set \text{recordtype='fixed'} choose \text{recl} to be the x-dimension of the array and define \text{file_type} to be \text{vms_fixed}. You must set \text{recordtype} in one of these two ways. By default, data is taken to be real (float in C), but this can be overridden in the filecap entry for a file type. There is also an entry for FITS files (FITS is the ‘standard’ image transport format for astronomical images). If you want to use a different file type you’ll have to learn about ‘\text{filecap}’ (see (undefined) [2-D Graphics], page (undefined)), or else see your local SM Guru.

So under VMS either your code should look like (\text{file_type} = \text{vms_var})

\[
\begin{align*}
\text{integer } i,j \\
\text{real arr(100,10)} \\
\text{c} \\
\text{open(2, file=filename, form='unformatted', recordtype='variable')} \\
i = 100 \\
j = 10
\end{align*}
\]

IMAGE
c now write your data into arr
   write(2) i,j
   write(2) arr
end

or, with file_type = vms_fixed,

   integer i,j
   real arr(100,10)
c
   open(2, file=filename, form=’unformatted’, recl=100, recordtype=’fixed’)    i = 100
   j = 10
c write your data into arr here
   write(2) i,j
   do 1 j=1,10
      write(2) (arr(i,j), i=1,100)
   1 continue
end

Under Unix, either of these programme fragments would work after omitting the record information from the open statement.

See (undefined) [Set], page (undefined) for an example of creating an image from scratch or a vector.

If you have an image defined (using the IMAGE command), you can extract a cross-section using the SET name = IMAGE ( expr , expr ) command. The two expressions give the (x,y) coordinates where you want the image to be sampled. For example,

   SET x=0,1,.01 SET z=IMAGE(x,0.5)

will extract a horizontal cross section through an image. You can also use IMAGE[expr,expr] to extract values via their indices, where either or both of the exprs may be * meaning "all values"; this is especially useful to those who like to use SM's images as a way of reading binary data.

An example of creating an image from scratch would be

   image (51,81) 0 1 0 1
   define NX image define NY image
   set ix=0,$NX*$NY-1 set iy=ix
   set iy=int(iy/$NX) set ix=ix - $NX*iy
   set x=ix/($NX-1) set y=iy/($NY-1)
   set image[ix,iy] = sin(x)*sin(y)

If you have a vector v of size NX*NY, you can say

   set image[*,*] = v

to convert it to an image. The data is arranged row-by-row (i.e. in the fortran order).

If you wanted to extract the top row of an image, after
define NY IMAGE define NX IMAGE
set ix=0,$NX-1

you can get the top row with any one of

set rr=image[ix,$NY-1]
set rr=image[do(0,$NX-1),$NY-1]
set rr=image[*,$NY-1]

If you want to add 100 to every value of an image, you can say

set image[*,*] = image[*,*] + 100

It’s obviously pretty easy to use SM to manipulate images point-by-point in this way.

You can write the current image to a file using WRITE IMAGE filename. Only a small subset of the images that SM can read can be written; currently your choices are "C", "CH", and "FITS"; all of these will write out floating point values (as images are stored as floats), and the FITS writer assumes that you have IEEE arithmetic, in conformity to the FITS standard. All current image keywords (i.e. those available via DEFINE name IMAGE) are written to the FITS header; you can define further keywords with IMAGE DEFINE name value.

Writing and reading images is an space- and time-efficient way of saving/rereading vectors in a binary format; if you use the FITS file format (i.e. set file_type to FITS) the data will be suitably byteswapped if necessary. For example,

data file.dat
read { x 1 y 2 z 3 }
image (3, dimen(x) )
set image[0,*] = x
set image[1,*] = y
set image[2,*] = z
image define filename file.dat
define file_type fits
write image save.fts

and then, in some other SM session:

define file_type fits
image file.dat
define filename IMAGE
set x = image[0,*]
set y = image[1,*]
set z = image[2,*]

Note well that defining the image as image(dimen(x), 3) would be far less efficient.

See also ARITHMETIC for how to extract a cross-section into a vector and DEFINE for defining a variable from the image header. Images may be displayed with CONTOUR or DITHER, and examined with IMAGE CURSOR.

KEY
Syntax: KEY

KEY key string

Define a key to generate a string. This is most often used simply to save typing some common command such as edit_hist. With the command KEY, you are prompted for the key to define, and the string. Because you are not using the history editor when you type the key, you can simply hit the key that you want defined, type a space, and then type the string terminated by a carriage return. The other form, where the whole command appears on one line, is probably more suitable for use in a macro such as your private startup macro (see under startup2 in the index). If you try entering it at the keyboard any special characters in key, such as ESC, will be interpreted by the history editor so you’ll probably have to quote the key with CONTROL-Q or ESC-q. Alternatively you can use ~ and printing characters , or octal numbers, to represent the escape characters in the same way as for EDIT (see (undefined) [Edit], page (undefined)). If key is given as pf# or PF# (where # is 1, 2, 3, or 4) it will be interpreted as a special function key on your keyboard in a terminal-independent way (see the description of termcap (see (undefined) [Termcap], page (undefined)) to see how these keys are defined). KEY definitions are listed along with other key bindings by the LIST EDIT command.

If the string ends in a \N, it will be executed the moment that the key is struck. (Note that this is \N not \n, which would have been interpreted as a newline.)

Only 10 keys can be defined, after that you’ll start overwriting earlier definitions (this is a result of the way that KEY was implemented; if it is a serious nuisance send us mail).

Syntax: LABEL str

LABEL writes the string str, which starts one space after LABEL and continues to the last non-space character, at the current location (set by RELOCATE, etc). After the label is written the current location is on the baseline, just to the right of the last character drawn. You can of course use quotes to include trailing white space. LABEL str is exactly equivalent to PUTLABEL 9 str (see (undefined) [Putlabel], page (undefined)).

The string's size and angle are determined by EXPAND and ANGLE. For more information on fonts and such like, See (undefined) [Labels], page (undefined).

Syntax: LEVELS WORD

LEVELS expr

Set the levels for the CONTOUR command to be the values of the vector WORD or to the values of the expression.
Syntax: LIMITS WORD WORD
LIMITS WORD Y1 Y2
LIMITS X1 X2 WORD
LIMITS X1 X2 Y1 Y2

LIMITS sets the coordinates of the plot region. All coordinates in RELOCATE, DRAW, etc, are referred to these limits. The various forms specify explicit limits for the x or y axis (X1 X2 or Y1 Y2), or default (specify the name of the vector to be used).

In fact, either or both of the WORDs may be replaced by ‘parenthesised expressions’, i.e. expressions in parentheses. For example,

LIMITS 0 5 (ln(y))

will scale the y axis according to the logarithm of vector y (but not produce a logarithmic axis - see TICKSIZE for this capability).

The current value of the minimum and maximum values on the x and y axes can be obtained with a DEFINE | command, e.g. DEFINE fx1 |.

If the two limits specified for an axis are the same, the limits for that axis will not be changed.

You can specify that the limits on one or both axes have a desired range using the RANGE command. This command affects the performance of the LIMITS command. If a non-zero RANGE has been set, LIMITS will ensure that the upper and lower limits differ by that amount. (e.g. after RANGE 2 0, LIMITS 0 1 0 1 is equivalent to LIMITS -0.5 1.5 0 1). If you specify a vector, the range is centred on the median value. If you have specified a range, and then ask for logarithmic axes with TICKSIZE, you may get complaints that logarithmic axes are impossible. Simply unset RANGE, and the problem should go away.

Syntax: LINES INTEGER INTEGER

Use only lines INTEGER1 to INTEGER2 from the current data file (specified with the DATA command). If VERBOSE is greater than 0, the lines actually read will be reported. LINES 0 0 will use the entire file, which is also the default following a DATA command. The variables $_l1 and $_l2 will be set to the first and last lines specified.

Syntax: LIST DEFINE [ begin end ]
LIST DEFINE |
LIST DEVICE [ pattern ]
LIST EDIT
LIST MACRO [ begin end ]
LIST SET
LIST TABLE
list all the currently defined variables (DEFINE) or macros (MACRO), optionally only within the range begin - end. If VERBOSE is 0 macros beginning ## won’t be listed. You can list the internal variables (i.e. those such as $fx1 that track SM internal variables) with LIST DEFINE |, or by setting VERBOSE to be two or more.

LIST EDIT will list all the keybindings. If VERBOSE is 0 only the keys that don’t generate themselves are listed (i.e. because A is bound to A it isn’t listed). If VERBOSE is 1, in addition all non-printing keys are listed, and if VERBOSE is 2 or greater all keys are listed. Both the EDIT and the KEY bindings are listed.

LIST DEVICE will list all the devices known to SM. The devices are listed with each device on an (indented) line, first the primary name, then a list of aliases in parentheses, then a full name. If pattern is provided only those lines that match the given pattern will be printed, for details on SM’s regular expressions See (undefined) [Apropos], page (undefined). An example would be

LIST DEVICE ^post
to list all devices whose principle name begins ‘post’.

LIST SET lists all currently defined vectors. For each vector the name, the dimension and the HELP field are given. See SET for how to set the latter.

LIST TABLE lists all columns available in the current TABLE; this currently only works for FITS binary tables.

For a list of the history buffer use HISTORY (macro lis), to list a macro use HELP (macro h). It can be useful to overload ‘list’ so that it doesn’t appear on the history list, and so that ‘list’ by itself corresponds to the command HISTORY (this is done for you if you use set_overload or put overload in your ‘.sm’ file).

Syntax: LOCAL DEFINE name value
DEFINE name LOCAL
LOCAL set name = expr
SET name LOCAL

Usually, SM’s variables (see (undefined) [Define], page (undefined)) and vectors (see (undefined) [Set], page (undefined)) have global scope, meaning that if you define one in a macro it is still defined when you return to the command prompt. This is often what you want, but not always; for example macros often define scratch vectors that must be explicitly deleted before returning. This is annoying, but a more serious problem is that two different macros can each set a vector called i, but mean different things.

The solution to this is to make your vectors and variables local to a macro, meaning that they are only visible within that macro, and from any called from it. This is really a nested scope rather than local, but LOCAL is easier to type. Such local objects are automatically destroyed when they go out of scope.

LOCAL
For example, if you define the macro `bar` as

```bash
macro bar 2 {
    echo $(goo)
    set goo local
    set goo=$1
    if(goo < $2) {
        bar $(goo+1) $2
    }
    echo $(goo)
},
```

the command `set goo=0 bar 1 5` will count from 0 to 5 and down again, and if you run the macro `yar` (defined as `macro yar { set foo local set foo=1
}`) the vector `foo` will not be defined at global scope.

Note that, as usual, you may have to be a little careful to ensure that you don't exit a macro before you expect. The symptoms would be that your local variable or vector was already destroyed, or that it referred to one at less restrictive scope (see ⟨undefined⟩ [Command Internals], page ⟨undefined⟩). The easiest fix is to add a comment line to the end of the macro.

---

**Syntax:** LOCATION GX1 GX2 GY1 GY2

Set the physical location of the plot. The plot region is the rectangle inside the box drawn by BOX. Vectors and points are truncated at the bounds of the plot region. LOCATION specifies (in device coordinates) where the plot region is located. LOCATION can be used to make an arbitrary size and shape plot, providing that you want it rectangular.

Because all devices have the same coordinate system in SM (0-32767), this command is considerably more useful than it used to be. The default LOCATION is 3500 31000 3500 31000. You can get at the current values of GX1 etc. using the DEFINE | command.

While you are using WINDOW (see ⟨undefined⟩ [Window], page ⟨undefined⟩), LOCATION commands have no effect. SM remembers them, however, and obeys the most recent one when you are finished with WINDOW.

See the RELOCATE ( x y ) command to draw labels outside the plot region, and DRAW ( x y ) to draw lines there.

If you want to increase the x-location by 500 (say), you can say:

```
LOCATION $(gx1 + 500) $gx2 $gy1 $gy2
```

This is sometimes useful to make room for an axis label; if your verbosity is 1 or higher you'll be advised of the appropriate displacement.

---

LOGICAL
Syntax: Logical Operators

The following logical operators are allowed on vectors and scalars in SM, where non-zero means true:

Unary:

!expr Logical Complement

Binary:

expr == expr Equal to expr != expr Not equal
expr < expr Less than expr <= expr Less than or equal
expr > expr Greater than expr >= expr Greater than or equal
expr && expr Logical and expr || expr Logical or

Only !, ==, and != are allowed for string valued vectors. All arithmetic vectors test unequal to all string-valued vectors.

For string vectors, there are three cases to consider: vstr1 == vstr2 generates a vector of the same length as vstr1 (with must be the same length as vstr2) by comparing the two vectors element by element; ’str1’ == vstr generates a vector of the same length as vstr by comparing each element of the vector vstr to the string str1; and ’str1’ == ’str2’ which returns a scalar by comparing the strings str1 and str2 (so it’s false in this example).

As in C, == has a higher precedence than &&, which in turn has higher precedence than ||.

Note that there is also a ternary operator, (expr1) ? expr2 : expr3 which has the value expr2 if expr1 is true, and expr3 if it is false.

See ‘arithmetic’ for the arithmetical operators See (undefined) [Arithmetic], page (undefined). You can test to see if a variable is defined by looking at the value of $?var (see (undefined) [Define], page (undefined)).

Syntax: LTYPE INTEGER
   LTYPE ERASE
   LTYPE EXPAND number

All lines except for those making up axes and characters are drawn with line type INTEGER, meaning:

<table>
<thead>
<tr>
<th>Integer</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>solid</td>
</tr>
<tr>
<td>2</td>
<td>short dash</td>
</tr>
<tr>
<td>4</td>
<td>dot - short dash</td>
</tr>
<tr>
<td>6</td>
<td>short dash - long dash</td>
</tr>
<tr>
<td>1</td>
<td>dot</td>
</tr>
<tr>
<td>3</td>
<td>long dash</td>
</tr>
<tr>
<td>5</td>
<td>dot - long dash</td>
</tr>
</tbody>
</table>

the default is a solid line, LTYPE 0. The current value of LTYPE is available as an internal variable (e.g. DEFINE ltype 1)

LTYPE
LTYPE ERASE and will erase any lines that are redrawn (e.g. LTYPE 0 BOX LTYPE ERASE
BOX will first draw a box, and then erase it). Not all devices can support erasing individual lines,
if yours doesn’t have to ERASE the whole screen. A convenient way to use LTYPE ERASE
is the undo macro. (in fact, LTYPEs 10 and 11 are used to implement LTYPE ERASE, LTYPE
10 to start erasing, LTYPE 11 to notify a device that you’ve finished doing so).

LTYPE EXPAND makes all dots, dashes, and spaces in the chosen ltype larger (or smaller) by
the value specified.

Syntax: LWEIGHT number

Set all lines to have a weight of number, where the bigger the blacker. Generally, an lweight of
0 is taken to be the hardware’s preferred width. The current value of LWEIGHT is available as an
internal variable (e.g. DEFINE lweight |)

Syntax: MACRO EDIT name

MACRO LIST [begin end]
MACRO name [ narg ] { body }
MACRO name [ narg ] < body >
MACRO name DELETE
MACRO name #1 #2
MACRO READ file
MACRO WRITE file
MACRO DELETE file
MACRO WRITE name [ + ] file

MACRO EDIT name allows you to edit a macro. All the commands available to the history
editor area available (including the ^ history), except that CONTROL-M inserts a line before the
cursor, CONTROL-N and CONTROL-P get the next and previous lines respectively, and CONTROL-V
and ESC-v move forwards and backwards 5 lines at a time. To exit use CONTROL-X (or whatever
you have bound to exit_editor). The macro need not exist, and both its name and number of
arguments can be changed by editing the zeroth line of the macro (CONTROL-P from the first line. If
this line is corrupted, or deleted, no changes are made to the macro when you exit. If the number
of arguments is negative, the macro will be deleted when you exit.) You may prefer to use the
macro ed instead of MACRO EDIT, as it doesn’t appear on the history list and, if invoked without
a macro name will edit the macro that you edited last. Incidentally, hm (‘help macro’) will list the
last macro that you edited with ed. The keybindings may be changed with READ EDIT.

LIST MACRO lists all currently defined macros, or all those which are between begin and end
alphabetically (asciily). If VERBOSE is 0, macros starting with ## are not listed.

MACRO name [narg] { body } defines name to be body, where name is a single word, and body
may be anything (most users need not worry about the form in angle brackets; it is occasionally
MACRO
useful when writing clever macros). A macro is invoked by typing its name. The optional `nargs` is the number of arguments the macro expects, default 0.

If the macro’s body is defined to be `delete`, the macro is deleted. `MACRO name DELETE` also deletes a macro.

Arguments are referred to as `$1, $2, \ldots $n$, up to a maximum of $9$. $0$ gives the name of the macro. If the number of arguments has more than one digit (e.g. 03 or 12), the macro is taken to have a variable number of arguments, between the ‘tens’ digit and the ‘units’ digit. For example, 12 means 1 or 2 arguments, 39 means between 3 and 9 arguments, and 02 means 0, 1, or 2. Confused? `HELP` will tell you what SM knows about a macro’s arguments. There’s one problem here; if you say

```
MACRO woosie 01 {
    if($?1) {
        echo An argument: $1
    } else {
        echo No arguments
    }
}
```

SM will interpret that 01 as the integer 1 before the macro’s defined, so that’s equivalent to `MACRO woosie 1 { ... }`. So you cleverly say `MACRO woosie "01" { ... }`; but that won’t work either as the closing " is seen before the 01’s parsed; you have to say `MACRO woosie "01 " { ... }` — and that does work.\(^3\) You don’t have to go through any such contortions in files read by `MACRO READ`, but they have their own problems.

If the number declared is greater than 99 the last argument will extend to the end of the line, and may consist of many words. When called, all the arguments must appear on the same line as the macro itself. This line may, as usual, be ended with an explicit \n. The macro can determine whether it has been supplied a given argument by using the `$?` construction (see `DEFINE`). It is also possible to change the values of arguments using `DEFINE` just as usual, and even to `DEFINE` arguments that you didn’t declare. These are temporary variables, local to the macro, and will disappear when you exit the macro.

Macros must end in space or newline, and if they don’t SM will silently add one (why? to prevent the macro stack being popped prematurely see `UNDEFINED` [Command Internals], page `UNDEFINED`). If you want to defeat this, end your macro with an explicit `#`, e.g. `MACRO echo {WRITE STANDARD#};
```

```
MACRO name #1 #2 defines macro name to consist of lines #1 — #2 of the history buffer. If #1 or #2 is negative it is interpreted relative to the current command, so saying `MACRO last2 -1
-2` will define a macro `last2` consisting of the last 2 commands issued.

\(^3\) See discussion of double quotes in see `UNDEFINED` [Quoting], page `UNDEFINED` if you want to know why.
MACRO READ file reads the macros in file and defines them. See RESTORE for how to also restore the history buffer from macro all.

MACRO DELETE file has the effect of deleting all macros defined in file.

MACRO WRITE file writes all currently defined macros to file in alphabetical order. If the file exists, and $noclobber is defined, SM will refuse to overwrite the file. You can set noclobber by specifying it in your ‘.sm’ file.

MACRO WRITE name [ + ] file writes the macro name to file. If the + is specified, or the file is the same as for the previous use of this command, the macro is written to the bottom of the file, otherwise the file is created. If the file exists and you aren’t simply appending, and $noclobber is defined, SM will refuse to overwrite the file. You can set noclobber by specifying it in your ‘.sm’ file.

Syntax: DEVICE META WORD
      DEVICE META CLOSE
      META READ WORD

If you open the special device called META it doesn’t close the current device, merely intercepts plotting commands and stores them away as well as executing them immediately. This continues until you issue a CLOSE command.

The command META READ reads a metafile and executes it on the current device. So to make hardcopy of a plot you could say something like:

    device x11
    device meta metafile.dat
    my_cunning_macro
    more_brilliance
    device meta close

after which (maybe after exiting SM and restarting it), you could say:

    device postscript
    meta read metafile.dat
    device 0

to make a hardcopy.

It is safe to concatenate metafiles together, if the fancy takes you.

Because of the way that SM interrogates devices about their abilities, while using META all ltypes, lweights, and fonts will be emulated in software (this guarantees that the device you playback on will be able to handle the code). If the current device can handle dots (i.e. PTYPE 0 0) then META will attempt to use them too, but if it can’t then META will be reduced to faking them. This could be a serious problem, so good luck. Metafiles do not support colour, again due to the impossibility of knowing if they will have the same behaviour as the original device.
Syntax: MINMAX min max

Set variables min and max to the the maximum and minimum values of an image read by the IMAGE command. Only that portion of the image within the current LIMITS is examined. This may be useful for setting contour levels, or doing a halftone plot (see the macro greyscale).

For example, the commands:

```
MINMAX min max
SET levs =$min,$max,($max-$min)/9
LEVELS levs
```

will choose a set of 10 levels which cover the complete range of the data.

Syntax: NOTATION XLO XHI YLO YHI

Set axis label format (exponential or floating). By default, all numbers between 1e-4 and 1e4 are written as floating point numbers, and all numbers outside this range are written with an exponent. This corresponds to a NOTATION -4 4 -4 4 command.

If you set XLO=XHI and/or YLO=YHI, all values on that axis will be plotted using exponents (including 1); as a special case if both XLO and XHI are 0 NOTATION will be reset for this axis.

If you want your positive and negative exponents to line up define the SM variable line_up_exponents; if it’s 1 they’ll be padded with a space, if 2 or more, with a + (you can do this in your `.sm' file).

Syntax: OVERLOAD keyword INTEGER

Allow “keyword” (in lowercase) to be used as a macro name if integer is non-zero. For example,

```
overload set 1 overload define 1
macro set { DEFINE } macro define { SET }
```

would interchange the meanings of the SET and DEFINE commands. The uppercase forms of the keywords retain their usual meanings. overload set 0 would reinstate the usual meaning of set. You may be surprised by the effects of overloading certain keywords. For example, if you overload help to mean DELETE HISTORY HELP, then set help vec help_string won’t work (you’d have to say set HELP vec ...).

This command is intended to be used for changing the default action of commands, rather than for a wholesale renaming of keywords! A more practical example than the above would be

```
overload erase 1 macro erase { del1 ERASE }
```

OVERLOAD
to prevent erase commands from appearing on the history list. See the macro `set_overload` for a set of definitions like this. It can be automatically executed by including an “overload” line on your ‘.sm’ file.

---

**Syntax: PAGE**

PAGE starts a new page for a hardcopy plot (n.b. the device driver for raster plots is unable to support multiple page plots).

On window systems (X11, SunView) page will raise the window and refresh it if necessary.

---

**Syntax: POINTS WORD1 WORD2 [ IF (expr) ]**

POINTS makes points of the current style (PTYPE), linetype (LTYPE), colour (CTYPE), size (EXPAND), and rotation (ANGLE) at the points in vectors WORD1 and WORD2. If the IF clause is present, only use those points for which expr (see the section on vector arithmetic) is non-zero. In fact, either or both of the WORDs may be replaced by ‘parenthesised expressions’, i.e. expressions in parentheses. For example,

```
POINTS x (1g(y))
```
to plot x against the logarithm of y.

In case you ever need to know, the distance from the centre of a point to a corner is 128 screen units when unexpanded, if the ASPECT (see (undefined) [Aspect], page (undefined)) ratio is unity.

---

**Syntax: PRINT [+][ file ][ 'format' ] { list }**

```
PRINT [+][ file ][ 'format' ] < list >
```

Print the vectors specified by list to file, if file is absent, print to the terminal (the output is paged, sort of). The name of each vector is printed at the head of the appropriate column. If the output is going to a file, each line of the header starts with a ‘#’, so the file can be read without using the LINES command.

The header is not printed if the variable `print_noheader` is defined and non-zero. For example, I have a macro

```
p 111
```

```bash
# print a vector or expression. E.g. "p x" or "p sin(x)"
local define print_noheader 1
local set foo=$1
if(whatis(foo) & 2**5) {
  print '%g ' { foo }
} else {
  print '%s ' { foo }
}
#
```

PRINT
to print vectors on a single line. In addition, no header is printed if you are not actually printing any vectors, in this case no newline is appended to the string. This provides a way of controlling string output, and suppressing newlines, e.g. PRINT 'S' {} PRINT 'M\n' {}. You probably will usually want to use WRITE STANDARD instead (see (undefined) [Write], page (undefined)).

With the optional ‘+’ the vectors are appended to the file, otherwise it is overwritten unless $noclobber is defined, in which case SM will refuse to touch the file. You can set noclobber by specifying it in your ‘.sm’ file.

The optional format string is of the type accepted by the C function ‘printf’, and you should see a book on C (or maybe the online system manual or help command) for more details. Basically, the format string is copied to the file with format specifiers beginning with % signs replaced by the numbers that you want printed. The format specifiers to use are the floating point ones, %e (exponential), %f (floating point), and %g (computer’s choice), d, o, x for printing numbers as integers (the latter two are octal and hexadecimal), or %s for strings. Fields are right justified by default, you can insert a - just after the % to left justify them. A % may be written as %% and a tab as \t. Lines are not terminated by a newline by default, you have to write them explicitly as \n.

For example,

```
SET x=1,10 SET y=x**2
PRINT file '%10f (%10.2e)\n' { x y }
```

will produce

```
#........x............y
#
..1.000000.(..1.00e+00)
..2.000000.(..4.00e+00)
..3.000000.(..9.00e+00)
(etc.)
```

where I have replaced each space by a . for clarity. If you say

```
PRINT '%g ' { x }
```

you will get

```
............x

1.2.3.4.5.6.7.8.9.10.
```

If you want very long output lines you’ll run into one of SM’s internal limits; the maximum length of a string (currently 160 characters). You might try to work around this by putting part of the formatted output into string vectors and then using a %s format to write it out; such an approach can be made to work, for example instead of

```
print file 'Date: %2d %2d %4d\n' { dd mm yy }
```

PRINT
you can write

```c
    set date = sprintf('Date: %2d',dd) + \\
    sprintf(' %2d',mm) + \\
    sprintf(' %4d',yy)
    print file '%s
' { date }
```

If you think that this is a hack I rather agree with you, but it does permit formatted output of up to 400 characters.

---

**Syntax: PROMPT new_prompt**

The current prompt is replaced by new_prompt; the default is :. Any occurrences of the character `*` are taken as instructions to ring the terminal bell. When you start SM your prompt is set to the value of the entry prompt in your `.sm` file (if you have one).

If you enter a partial command (e.g. `macro foo {` or `echo ABC\`) SM switches to a different prompt. By default this is `>>`, but if you define the variable prompt2 that will be used instead. You can set prompt2 in your `.sm` file.

---

**Syntax: PTYPE n s**

PTYPE WORD

PTYPE ( expr )

PTYPE { list }

PTYPE n s causes points to be drawn as n sided polygons of a style s, where s refers to:

0  
1  open
2  skeletal (center connected to vertices)
3  starred
4  solid

For example, PTYPE 1 1 (or PTYPE 0 0) makes points appear as dots, PTYPE 4 1 (the default) makes (diagonal) crosses, and PTYPE 6 3 makes filled hexagons. Points made up of lines (types 0, 1, and 2) are drawn using the current LTYPE.

When possible PTYPE 0 0 will draw the smallest possible dots that the device is capable of; these may or may not be different from PTYPE 1 1.

The current value of PTYPE is available as an internal variable (e.g. `DEFINE ptype |`)

PTYPE WORD or PTYPE ( expr ) use vector WORD or the expression expr as its source of n and s, ( so you may define different point types for each point) except that the numbers are contracted together. If the entry has a fractional part, it is treated as an expansion factor, relative
to the current expansion (no fractional part means default expansion); so if \( n \) is a vector giving the desired number of sides for a set of points, \( s \) is a vector giving the desired types, and \( e \) is a vector giving the desired relative sizes \((0 \leq e < 1)\), you’d want to say \( \text{PTYPE} \ (10*n+s+e) \). For example, an an entry of 103.5 in \( \text{WORD} \) is the same as \( \text{PTYPE} \ 10 \ 3 \), \( \text{EXPAND} \ 0.5 \), but if you now say \( \text{EXPAND} \ 2 \) the net expansion will be unity. It’s much easier to use a vector of expansions directly to the \( \text{EXPAND} \) command, but fractional ptypes are preserved for backwards compatibility. N.b. due to a bug in X10R4 for the Sun, \( \text{PTYPE} \ n \ 3 \) does not work for \texttt{dev xwindows} on a sun. If more points are specified than the dimension of expr, the first element will be used for the excess.

If \( \text{WORD} \) is a string-valued vector, its elements are used to label the points of the graph. They are drawn at the current expand and angle (vector-valued EXPANDs and ANGLEs are ignored), and in the current default font. For \TeX-\string\texttt{string} users this can be specified with the variable \texttt{default\_font}, which can either simply be defined, or set in your ‘.sm’ file.

\texttt{PTYPE} \{ \texttt{list} \} defines the symbol to use with the \texttt{POINTS} command to be some creation of the user. The list consists of a set of \( c \ x \ y \) where \( c \) is a letter, and \( x \) and \( y \) are integers. If \( c \) is ‘m’ or ‘r’ (move or relocate) the plot pointer is moved to the point \((x,y)\), if it is ‘d’ (draw) or absent a line is drawn from the current position to the point \((x,y)\). The coordinates are measured relative to the current point being plotted, and are measured in screen coordinates (i.e. 0-32767). Both \texttt{EXPAND} and \texttt{ANGLE} are applied to the \((x,y)\) values as usual.

As an example the command

\texttt{PTYPE} \{ \texttt{m} \ 0 \ 500 \ 500 \ 0 \ -500 \ -500 \ 0 \ 0 \ 500 \}

will define the marker to be a diamond, something like:

\[
\begin{array}{c}
/ \ \ \ \ \ \\
/ \ \\
\ \\
/ \ \\
\end{array}
\]

(but with unbroken lines). As a more useful example, there is a macro \texttt{upper} which defines a variable \texttt{$upper} to draw an upper limit sign, used as

\texttt{PTYPE} \texttt{$upper}

(if ANGLE were 180, they’d be lower limits).

\[\text{Syntax: PUTLABEL INTEGER str}\]

\texttt{PUTLABEL} writes a label at the current location with rotation and size specified by \texttt{ANGLE} and \texttt{EXPAND} (exactly like \texttt{LABEL}). The label is centered with respect to the current location according to the argument \texttt{INTEGER} which can be 1 - 9 meaning that the label is:

\texttt{PUTLABEL}
(cf. a vt100 keyboard) To be a little more precise, ‘above’ means that the string’s baseline (the bottom of characters such as ‘a’ that have no descender) is at the level of the current point, while ‘below’ means that the top of the tallest character in the string is level with the current point. If you don’t like this neglect of descenders, try

MACRO myputl 102 {label \raise\advance\depth{$2}by100{}\n putlabel $1 $2}
myputl 7 This is a Label

(You can then say overload putlabel 1 macro putlabel {myputl} if the mood takes you). After the label is written the current location is on the baseline, just to the right of the last character drawn. If \texttt{INTEGER} is 0 the string isn’t actually drawn, but the string’s dimensions are calculated (and are available as \texttt{$\text{swidth}$, $\text{sheight}$, and $\text{sdepth}$}), and any \LaTeX\ definitions are remembered. If PUTLABEL 5 isn’t quite what you want (as it centres vertically as well as horizontally), try LABEL \texttt{\centre{H\_\alpha}} instead.

See \texttt{\undefined{Labels}}, page \texttt{\undefined{Labels}}, for a description of how to enter a label with funny characters, sub- and super-scripts, and so forth.

If EXPAND is set to exactly 1, and ANGLE is exactly 0, then SM will use hardware fonts, when available, in writing labels. This is faster, but if you don’t like it say “EXPAND 1.00001”, or use a \texttt{\r} explicitly to select the roman font. Or ask your SM Guru to edit the ‘graphcap’ file to stop your printer from ever using hardware fonts (or read the discussion under LABEL).

\begin{center}
\begin{tabular}{ccc}
\textbf{above} & left & centre & right \\
7 & 8 & 9 \\
centered & 4 & 5 & 6 \\
below & 1 & 2 & 3 \\
\end{tabular}
\end{center}

Syntax: \texttt{QUIT}

Quits the programme entirely.

The macro ‘q’ is defined as something like

\begin{verbatim}
DELETE HISTORY DEFINE 1 0      # default value
DEFINE 1 ? { Are you sure? Enter 1 to really quit }
IF($1) { QUIT }
\end{verbatim}

so you won’t quit accidently, and the QUIT won’t appear in the history file. This is an obvious candidate for overloading.

Syntax: \texttt{RANGE number_x number_y}

If number is non-zero, set the range on the x or y axis to be number, so LIMITS will choose two values that differ by number. Nothing will happen until you issue a LIMITS command.
For instance, if you wanted to ensure that the y axis of a logarithmic plot spans exactly two
decades the commands RANGE 0 2 LIMITS x y would choose suitable y limits, with actual values
appropriate for the y vector (in fact symmetrical about the median value).

**Syntax:** READ WORD INTEGER
- READ [ ! ] { WORD INTEGER WORD INTEGER ... }
- READ [ ! ] { ... WORD range ... }
- READ ROW WORD INTEGER
- READ [ ! ] ‘format’ { WORD WORD ... }
- READ EDIT WORD
- READ OLD WORD WORD
- META READ WORD WORD

READ WORD INTEGER reads a column of data from the file specified by the DATA command,
using the lines specified by LINES. Columns may be separated by white space (blanks or tabs) or
by a comma, or by some combination of the two. It’s OK if some of the columns contain text,
providing that you don’t try to read them. You can read text columns into string vectors, as
described in the next paragraph. The data is read into the vector WORD, which will be created, from
column INTEGER. Any field beginning with a * is taken to be ‘empty’, and is assigned the value
1.001e36. Any line beginning with a # is skipped over (and printed if VERBOSE is greater than
1), any line beginning with a ! is skipped and always written to the terminal. Long (logical) lines
may be spread over several (physical) lines by ending the line with a \; no line may exceed a total
of 1500 characters. If you use continuation lines, note that SM’s line numbers (for example, as set
with the LINES command) apply to logical not physical lines; a continued line counts as only one
line.

You can optionally specify a type of vector by adding a suffix onto the integer; ‘.f’ (the default)
means floating point, ‘.d’ or ‘.i’ means integer, ‘.s’ means string-valued. String valued vectors can
be used as input to PTYPE commands, or simply for reading columns from data files that you
want to PRINT.

READ { WORD INTEGER WORD INTEGER ... } is the same as repeating READ WORD INTEGER for
each vector, but more efficient as it only has to read the file once.

READ { x 1 s 5 . s y 2 . f z 3 . i }

will read columns 1 and 2 into floating point vectors x and y, column 3 into an integer-valued
vector z, and column 5 into string-valued vector s. As noted below, you can omit the INTEGERs
by specifying an empty format: READ " { x y } (those are two single quotes).

Usually SM stops reading at the first invalid line, but if you say READ ! all the lines specified
with LINES (or the entire file) are read. Missing numerical fields are set to be invalid (i.e. they are
treated as *); missing string values are left blank. This is probably most useful with the %n format
specifier.
If INTEGER is invalid (\(\leq 0\)), the contents of the file are written to the standard output. READ ROW is very similar, but the values are read from row INTEGER of the file (any LINES command is ignored). The same type qualifiers are allowed as for reading columns. There is no limit to the number of elements in the vector, except that implied by the maximum length of a line. You cannot specify a range of columns to read with READ ROW, but try

```plaintext
SET i=2,5
READ ROW x 1
SET x=x[i]
```

If the first field is a string, you can say READ ROW s 1.s SET x=ATOF(s[i]).

If your data is in a number of columns (e.g. you have written it out to a file ten values to a line) you can specify a range of columns, for example

```plaintext
READ { x 1-4 y 5 z 6-10 }.
```

You can only use ranges for numerical vectors, and only with the list form of READ. Ranges won’t work if there is a short line at the end, but you can still say something like

```plaintext
LINES 0 100
READ { x 1-4 }
READ ROW _x 101
SET x=x CONCAT _x
```

which will be almost as efficient if you have defined \$save_read_ptr.

In order to speed up multiple reads of the same file, SM usually remembers where it got to in a file; this is disabled if you undefine the variable \$save_read_ptr (which can be done in your `.sm' file by setting it to 0). The remembered position is forgotten every time that you issue a DATA command, or try to re-read part of the file. You can get into trouble if you read part of a file, modify the file without reissuing a DATA command, and then read some more, but in normal usage it should be safe to leave saving the read pointer enabled.

Instead of using simple column-oriented input it is possible to specify a format similar to those used by C’s `scanf' functions (Fortran formats are not supported); if you don’t know C then most of what you need to know is that characters in the input must match those in the input file, except that items to be read are specified with format strings that start \%. For example, a format \texttt{abc%f:%f} expects the input to consist of \texttt{abc} then two floating point numbers separated by a colon. If the \% is followed by a \* the field is read but isn’t assigned to a vector. You can specify a newline as \texttt{\n} or a tab as \texttt{\t}.

As a further example, if your data file has lines like

```
1:12:30 -45:30:11
```

you could read it with

```plaintext
read '\%d:\%d \%f:\%f:\%f' { hr min sec deg dmin dsec }.
```

```plaintext
READ
```
The type of the vector is deduced from the format string; you can’t use `.f` or `.s` in the vector list (why would you want to specify a type twice?).

As a special case, of you specify an empty format ("") the named vectors are read as floats from the first n columns of the file, so

```
READ '' { x y z }
```

is equivalent to

```
READ { x 1.f y 1.f z 3.f }
```
or simply

```
READ { x 1 y 1 z 3 }
```

I said that the %-formats were ‘similar’ to `scanf`’s; they differ in the way that they treat field widths and white space. If you don’t specify a width at all SM follows the usual C behaviour of skipping white space between items; if you do specify a field width no space is skipped over before the field begins. You can always explicitly skip spaces with a `%*[ ]` format. The `%n` format returns the number of fields matched rather than the number of characters.

The supported format letters are `d`, `e`, `f`, `g`, `o`, `n`, `s`, `x`, and `[`, their meanings are:

- `%d` Read an integer into a floating vector (‘d’ stands for ‘decimal’). If a field width is specified trailing spaces are treated as spaces not zeros – this isn’t fortran you know. The field " 1234 " (i.e. a field width of 6, `%6d`) has the value 1234 not 12340.
- `%e`
- `%g`
- `%f` Read a floating point number with or without an exponent into a floating vector. As for `%d`, trailing spaces in a fixed-width field are treated as spaces not zeros.
- `%n` Return the number of fields that are already correctly matched in the current line; this is only useful in conjunction with READ !.
- `%o` Like `%d`, but the number’s taken to be octal.
- `%s` Read a string into a string-valued vector. If a field width is specified the entire field is read spaces and all; if there is no width initial spaces are skipped as usual and the string is terminated by the first white space character.
- `%x` Like `%d`, but the number’s taken to be in hex.
- `%[...]` Read a string consisting of the characters ... into a string valued vector. You can specify a range as `a-z` so `%[a-zA-Z0-9]` would read a string consisting of any lower case character or digit, or one of A, B, or C. If the first character is `^`, read any characters except those specified (e.g. `%[^abc]` reads anything but the letters a, b, or
c). If a field width is specified characters that don’t match those specified at the end of the field are ignored.

%% Not a conversion format, but a literal %.

READ EDIT WORD reads a new set of keybindings from the file WORD. The format and syntax are given under History (see \{undefined\} [History], page \{undefined\}) in the introduction.

READ OLD WORD1 WORD2 defines macro WORD1 to be the contents of file WORD2. This is provided for compatibility with Mongo (see \{undefined\} [Mongo], page \{undefined\}) and the read_old macro. You no longer need use read_old to read SM history files, use RESTORE instead.

If VERBOSE (see \{undefined\} [Verbose], page \{undefined\}) is greater than 0, the lines actually read will be reported.

META READ WORD reads a metafile, as produced with the pseudo-device META, and executes the enclosed commands on the current device.

---

Syntax: RELOCATE X Y
RELOCATE ( X Y )

The first form sets the current position to (X,Y) in user coordinates without drawing a line. The second (with parentheses) sets the position in ‘screen’ coordinates, i.e. 0-32767. The current position is used by the DRAW, LABEL, and PUTLABEL commands.

There are a couple of pairs of internal variables ($uxp,$uyp) and ($xp,$yp) that give the current position of the plot pointer, either in user or screen coordinates.

---

Syntax: RESTORE [ filename ]

Restore all the current macros, variables, and vectors from file filename (if omitted the default is to use the value of save_file in your ‘.sm’ file, or failing that ‘sm.dmp’). In addition, the current history buffer is replaced by the macro all if defined in the RESTOREd file.

The file should have been written by the SAVE command, and RESTORE will treat any other file type as if it were a SM history file and add its commands to the end of the current history list.

If VERBOSE (see \{undefined\} [Verbose], page \{undefined\}) is greater than 0, some extra information is printed.

---

Syntax: RETURN

RETURN
Return from the current macro, which includes breaking out of DO and FOREACH loops. If you are not executing a macro, simply return to the prompt (this is more or less equivalent to typing CONTROL-C).

A RETURN can be useful while playing with fiddling with data interactively. For example, if you want to playback a set of commands, but then do other things when the plot has appeared, you could put a RETURN after the desired part of the playback buffer. (This doesn’t work quite the way that you might naively think. Playback works by defining a macro all from the history list, and then executing it. The RETURN is actually returning from this macro, rather than directly from the command list, but the effect is the same. If RETURN always returned directly to the prompt, macros such as hcopy wouldn’t work.)

If VERBOSE is 2 or more, the name of the macro being returned from is output.

If the very last command in a macro is RETURN then the RETURN will take place, not from the desired macro, but from where the macro was called from. You can work around this by putting a space after the RETURN, or simply omitting it as it isn’t doing anything anyway. If a RETURN comes last on a history list, this problem will lead to macros such as hcopy not working correctly.

---

Syntax: SAVE [ filename ]

Save some or all of the current macros, variables, and vectors in file filename (if omitted the default is to use the value of save_file in your ‘.sm’ file, or failing that ‘sm.dmp’). The current history buffer may also be saved, as the macro all.

You are prompted for whether you want to save variables, vectors, and macros (which includes all, the current playback buffer). Macros beginning ## are not saved, as they are assumed to be system macros. Variables and vectors whose names start with a ‘.’ are assumed to be temporaries, and are not saved either.

The opposite to SAVE is RESTORE (see [Restore], page [undefined]). You may want to use the MACRO DELETE WORD command to undefine macros from e.g. the ‘utils’ macro file. See, for example, the macro sav (which can be overloaded).

If VERBOSE (see [undefined]) is greater than 0, some extra information is printed.
Syntax: SET name = expr
  LOCAL SET name = ...
  SET name = { expr }
  SET name = < expr >
  SET name = expr IF ( expr )
  SET name = expr1, expr2 [, expr3 ]
  SET name = expr1 ? expr2 : expr3
  SET name LOCAL
  SET DIMEN ( name ) = INTEGER
  SET name = WORD ( [ WORD [ , WORD ... ] ] )
  SET name [ expr ] = expr
  SET name [ expr, expr ] = expr
  SET IMAGE[expr, expr] = expr
  SET HELP WORD [ rest ]
  SET RANDOM s_expr

Conduct various operations on vectors of data. The simplest, SET name = expr sets vector name to be equal to the expression expr. If the IF clause is present, name will only contain those elements of expr for which it is true (non-zero). A special case of an expression is simply a list of values within braces (or angle brackets).\(^4\) For string-valued vectors, the only allowable expressions are a string-valued vector, the CONCATenation of two string vectors, the addition (i.e. element-by-element concatenation), or a string in single quotes (e.g. SET s='Hello, World' or SET ss='n_{e cl co g } + }').

Within a macro, any of these commands that set an entire vector may be preceded by the word LOCAL. This ensures that the vector name is only visible within that macro, and any called from it (see (undefined) [Local], page (undefined)). Future references to the name automatically refer to the local vector, so only the first occurrence need be preceded by LOCAL. Such local vectors are automatically destroyed when they go out of scope; in fact it is illegal to delete one explicitly.

An equivalent way to achieve this is with the command SET name LOCAL, after which the vector may be SET in local scope (so SET x LOCAL SET x=10 SET x=20 is equivalent to LOCAL SET x=10 SET x=20).

Note that, as usual, you may have to be a little careful to ensure that you don’t exit a macro before you expect. The symptoms would be that your local vector was already destroyed, or that it referred to one at less restrictive scope (see (undefined) [Command Internals], page (undefined)). The easiest fix is to add a comment line to the end of the macro.

With expressions separated by commas the SET command is like a DO loop, setting name to be the values between expr1 and expr2, at increments of expr3 (which defaults to 1). You can

---
\(^4\) You are not allowed to use commas in such a list, so set x={1, 2, 3, 4 } makes x a string vector; but set x=atof(x) soon fixes that (or say set x=atof({1, 2, 3, 4 }) in the first place). You can use index and substr to achieve the same result for truly string-valued vectors.
also use an implicit DO as part of an expression, e.g. SET x=1 + do(0,10,2)/10 (see (undefined) [Arithmetic], page (undefined)).

The command with ? and : is similar to the C ternary operator. If expr1 is true, take the corresponding value of name for expr2, otherwise use expr3. This command is worth learning, as it can often be used to replace a DO loop. This command is in fact simply a special case of SET x = expr.

If you have a DO loop that calculates each element of a vector in turn, something that is possible if inefficient in SM, you need to define a vector before you use it. You will also need to declare a vector (or create it by putting it on the left of a SET command) if you want to use a vector-valued subscript on the left of an expression. This can be done with the SET DIMEN(name) = INTEGER, which also initialises it to 0. Thus SET DIMEN(y) = DIMEN(x) is equivalent to SET y = 0*x. You cannot use expressions as the dimension, but SET y = $(4 + 4)$ works perfectly well. You can optionally specify a qualifier to the dimension, in just the same way that you can specify a qualifier to a column in a READ command, so SET DIMEN(s) = 10.s declares a 10-element string-valued vector. See also SET WORD [ expr , expr ] = val.

SET name = WORD ( [ arg , arg... ] ) allows you to use a macro as a sort of function definition. Within the macro WORD any assignment to $0$ has the effect of assigning to name, and the other arguments behave as normal. The arguments arg can be words or numbers (but not general expressions) and are separated by commas. Note that this is a change to the syntax of this command! Previously only one argument was permitted, but it could be an expression, and the result was returned by assigning to $1$ in a rather confusing way.

SET word[expr] = expr sets the elements expr of vector word to the values of the vector on the right hand side. If the left hand side is a string but the right hand side is numerical it will be converted. The first expr is converted to an integer before being used as an index; if it is too small it’s set to 0, if too large to the largest allowable index. For example,

```
set i=0,10 set x=100*i
set dimen(y) = dimen(x)
set y[i-1] = x
```

will result in a complaint that -1 is an invalid index and set $y = \{100 200 300 \ldots \}$. Note that arrays are subscripted with [ ] not (), and that, as always, indices start at 0 not at 1. The word must exist before you can do this to it.

If your range of indices is contiguous you can say:

```
set x[0,10] = y
```

instead of

\footnote{you can often do better with a ?; or SET WORD[expr] = expr command}
set i = 0, 10
set x[i] = y

As a bonus the vector x will be extended as needed to accomodate the new elements. This means that

set x = x CONCAT y

is equivalent to

set x[dimen(x), dimen(x) + dimen(y) - 1] = y

If you have pre-allocated x to be large enough, the latter is (maybe much) more efficient.

This also provides a way to generate a vector initialised to a desired value:

set x[0, 100] = 10

SET IMAGE[ix,iy] is used to set elements of an image to the specified values. The image must exist (see (undefined) [Image], page (undefined)), and the vectors ix and iy are interpreted as integer subscripts into the image (0-indexed, of course). This is the inverse of the SET z=image[ix, iy] and isn’t quite the same as the SET z=IMAGE(x,y) command, as x and y are interpreted with using the (optional) xmin, xmax, ymin, and ymax values. In the old days, this command was set image(ix,ix) = ..., but this was confusing and is now deprecated.

SET HELP sets the help string for a vector; the rest of the line is read, and will be returned in response to a HELP WORD request. It can also be used in the string-valued expression HELP(name), for example YLABEL $(HELP(yvec))$.

SET RANDOM number sets the seed of the random number generator used by the RANDOM operator; if you don’t set it yourself it’ll be set to some value based on the time since 1970.

Let’s look at some examples.

SET y = $v1 + 5.0 * x

This sets each element of the vector y to be the value of the scalar $v1 plus 5.0 times the corresponding element of the vector x (assuming that x has been defined previously)

SET data_set_1 = lg(x) IF ( lg(x) > 0)

This sets the elements of the vector data_set_1 to be the (common) logarithm of the corresponding element of the vector x, if that logarithm is > 0. Thus data_set_1 will in general be of smaller size than x.

SET data = (lg(x) > 0) ? lg(x) : 0

In this case, data_set_1 will be the same size as x, and any elements of data_set_1 where the corresponding element of x is less than or equal to 1, will be set to 0.

SET vec = 4*{ 1 1.5 2 2.5 3 }
will define a vector \textbf{vec}, with 5 elements, with the values given by four times those in the list.

\texttt{SET \texttt{vec} = 1,12,2}

an alternative way of defining the same values.

\texttt{SET \texttt{i} = \{ 2 3 \}}
\texttt{SET \texttt{x} = \texttt{vec}[i]}

will set the vector \texttt{x} to have be \texttt{8 10} (i.e. \texttt{vec}[2] and \texttt{vec}[3]).

\texttt{MACRO \texttt{pow} 2 \{ \texttt{SET} \ \texttt{$0} = \texttt{$1} ** \texttt{$2} \} \texttt{SET \texttt{vec} = \texttt{pow(\texttt{vec} , 3)}}}

cube the vector \texttt{vec}.

\texttt{SET \texttt{vec[0]} = 2*\texttt{pi}}

Change your mind about the first element of \texttt{vec}.

\texttt{SET HELP pam \texttt{Wichita, Kansas, July 7, 1953}}

will set the help string for vector \texttt{pam} to be the string \texttt{Wichita, Kansas, July 7, 1953}, so when you type \texttt{HELP pam}, this string will be printed out.

\texttt{SET \texttt{rhl}=Robert}

defines a string vector with one element.

\texttt{SET \texttt{DIMEN(rhl)} = 10.s}

defines a string vector with ten elements (all blank), while

\texttt{SET \texttt{rhl}=\{Robert Horace Lupton\}}

defines a string vector with initialised elements, and

\texttt{SET \texttt{rhl[1]}=Hugh}

corrects it.

See the CURSOR command for defining a pair of vectors using the cursor to mark the points, and SPLINE for how to fit splines to pairs of vectors.

\underline{Syntax:} \texttt{SHADE INTEGER pexpr pexpr}
\texttt{SHADE HISTOGRAM INTEGER pexpr pexpr}

(‘Pexpr’ is the name of a vector, or an expression in parentheses, e.g. \texttt{SHADE 1000 x (sqrt(y))}.)

Shade ‘inside’ a curve defined by the expressions. The shading is rotated through the current value of \texttt{ANGLE}, and lines are spaced \texttt{INTEGER} apart (screen coordinates, so the full screen is 32768 across). If \texttt{INTEGER} is 0, the lines will be drawn as close together as the device allows, simulating an
area fill. This is a very inefficient way to fill areas, made only slightly better by specifying a large
LWEIGHT on devices that support such things in hardware (you'll also get slightly jagged edges).

The meaning of 'inside' is that as the shading is done, from left to right taking the value of
ANGLE into account, lines are drawn from every odd to every even crossing of the curve. The curve
is considered as being closed by joining the first to the last point. If a shading line just touches
the curve the algorithm may be confused, change INTEGER slightly, or adding 180 to ANGLE.
Sometimes joining the ends of the curve may not be what you want, try using CONCAT to add points
on the end yourself. For example,

```
SET x=0,10 SET y=x**2 LIMITS x y SHADE 1000 x y
```
looks like a new moon, but

```
SHADE 1000 (x CONCAT 10) (y concat -1e10)
```
shades beneath the curve, for ANGLE 0 that is. You could also try the macros scribble and shading
in demos, e.g. type load demos scribble.

SHADE HISTOGRAM is similar, but it shades the histogram that would be drawn by HISTOGRAM
from the same set of points. In this case the area to be shaded lies between the histogram and the
line y=0. If this offends you, offset the whole graph and lie about the axes.

Syntax: SHOW

List the values of some of the internal variables, including current location and plot region limits
in user and device coordinates, the value of the expansion and angle variables, the line type and
weight, and the physical limits. Show is actually a macro, so you could modify it to your own ends,
for example listing the current data file too.

Syntax: SORT { vector_list }

Sort the first vector in the list into increasing numerical order, and rearrange the others in the
same way. The maximum number of vectors that can be sorted is 10. For example, following the
commands

```
SET e = { 2 7 1 8 2 8 1 8 2 } SET p = { 3 1 4 1 5 9 2 6 5 }
SORT { e p }
```
the vectors e and p would be 1 1 2 2 2 7 8 8 8 and 4 2 3 5 5 1 1 9 6. The order within the p
vector is not defined when the e values are identical.

Any mixture of string- integral- and arithmetic-valued vectors is allowed; the only exception is
that if the first (i.e. key) vector is integral, it'll be converted to floating before being used.

SPLINE
Syntax: SPLINE x1 y1 x2 y2

Fit a natural cubic spline through the points specified by vectors x1 and y1. The dimensions of x1 and y1 must be the same and must exceed 2, x1 must be monotonic increasing (use SORT if necessary). When the spline has been fit, take the points specified in vector x2, and fill the (new) vector y2 with the corresponding values. Linear interpolation is used beyond the ends of x1.

Strings

SM supports a number of string operations on vectors and scalars. In the following descriptions expr is a expression and vector the name of a vector.

Unary:

ATOF(expr)

The value of expr converted to a floating point number. If an element of the expression cannot be so interpreted (i.e. it doesn’t start with an optional sign followed by a digit), the value returned will be 0.

CTYPE(STRING)

Return a vector with the names of all currently defined colours; there is also CTYPE() to recover their values (see (undefined) [Arithmetic], page (undefined)).

HELP(name)

The help string associated with vector name (set with SET HELP)

LENGTH(expr)

The length (SCREEN units) that a string would have if plotted

STRLEN(expr)

The number of characters in a string

STRING(expr)

Convert a number to a string. You might prefer to use sprintf('%t',expr) instead, as it gives you more control.

STRING<WORD>

Convert a string to a string, quoting ". You don’t usually need to use this (simple write 'my string'), but if your string already contains quotes this doesn’t work.

(expr)

Raise precedence

Binary:

expr + expr

Add; concatenate element by element

expr CONCAT expr

Concatenate the two vectors
INDEX(expr_1,expr_2)
Return the starting index of expr_2 in expr_1, or -1 if not found.

SPRINTF(expr_1,expr_2)
Format expr_2 using the standard C format string expr_1. The additional format %t
or %T is identical to %e, but formats the string as a power of 10 in TeX format. Note
that only one expr may be formatted, but that you can say sprintf(expr,expr) +
sprint(expr,expr) ... to work around this restriction.

vector[expr]
The elements of vector given by expr.

Ternary:

SUBSTR(expr_1,expr_2,expr_3)
Return the substring of expr_1 that starts at expr_2 and is expr_3 characters long. If
expr_2 is negative, count from the end of the string; if expr_3 is 0 return the rest of
the string. For example, 'Dr. ' + substr('Ralph Monger',-6,0) would return 'Dr.
Monger'.

expr1 ? expr2 : expr3
expr2 if expr1 is true, else expr3

Node that this is similar to the corresponding SET command, but it needs parentheses if used as
an expression.

All indices, as elsewhere in SM, start at 0; e.g. substr('Algonquin',0,1) is A.

The expression VECTOR[expr] results in a vector of the same dimension as the expr, with
elements taken from VECTOR (i.e. VECTOR[INT(expr_i)]).

You can also use WORD([ expr [ , ... ]]) as part of an expression, where WORD is a macro taking
zero or more arguments. The arguments are restricted to be either the names of vectors or numbers;
sorry.

You can use the usual logical operators (see (undefined) [Logical], page (undefined)) with string-
valued vectors; there's a discussion in that section of the confusions that people conjure up about
when they need to use ' '.

The HELP(name) string operator is often useful in labels, for example

SET HELP size "r_e"
...
XLABEL $(HELP(size))

The precedences are what you'd expect, with + being higher than CONCAT. The logical operators
have even lower precedence than CONCAT.
Syntax: \texttt{SURFACE type z1 z2} \\
\texttt{or \quad SURFACE type z1 z2 \ WORD \ WORD}

Draw a wire-frame surface of the current \texttt{IMAGE} from the point defined by \texttt{VIEWPOINT}. If the \texttt{WORD}s are omitted a line in the surface will be drawn for each row and column of the image; if the \texttt{WORD}s are present they will be taken to be the $x$- and $y$-coordinates of the desired lines, and \texttt{SM} will interpolate in the image to determine the corresponding values (see also the hundreds digit of type, below).

The command \texttt{VIEWPOINT} specifies the position of the observer and the type of projection used (see (undefined) \cite{undefined}).

The last digit of \texttt{TYPE} is used to determine which surface to draw:

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>no hidden line removal</td>
</tr>
<tr>
<td>1</td>
<td>draw top surface</td>
</tr>
<tr>
<td>2</td>
<td>draw bottom surface</td>
</tr>
<tr>
<td>3</td>
<td>draw both top and bottom surfaces</td>
</tr>
</tbody>
</table>

If \texttt{type}'s tens digit is set, \texttt{SURFACE} will use the current limits (as set with \texttt{LIMITS}) rather than autoscaling them from the data.

If \texttt{type}'s hundreds digit is set, the two \texttt{WORD}s are taken to be the $x$- and $y$-coordinates corresponding to the rows and columns of the \texttt{IMAGE}, but no interpolation is done. For example, after

\begin{verbatim}
IMAGE (11,11) \\
SET ix=0,10 \\
set xs=0,10,2 \\
do y=0,10 { \\
    SET IMAGE(ix,$y) = \cos(0.2*ix)\sin(0.4*$y) \\
} \\
VIEWPOINT 30 -10 -1 \\
SURFACE 3 -1.1 1.1 xs xs
\end{verbatim}

will draw a 2-sided surface, drawing 21 lines in each direction on the surface. If, on the other hand, the data were really only known on an irregular set of $x$- and $y$-values, you could say something like

\begin{verbatim}
IMAGE (11,11) \\
SET ix=0,10 \\
SET x = { 0 1.3 2.4 3 4 4.5 4.6 6.7 8.2 9.6 10 } \\
SET y = { 0 0.4 0.9 1.2 2.718 3.14 4.2 5.4 6.667 9.1 10 } \\
do i=0,10 { \\
    SET IMAGE(ix,$i) = \cos(0.2*x)\sin(0.4*y[$i]) \\
} \\
CTYPE cyan \\
SURFACE 103 -1.1 1.1 x y \\
CTYPE default
\end{verbatim}

to draw the same surface.
\(z_1\) and \(z_2\) are the limits used for the z-axis; you might want to set them with \texttt{MINMAX}. The surface drawn will be truncated at \(z_1\) and \(z_2\) unless you are using an axonometric projection (see (undefined) [Viewpoint], page (undefined)).

There are some useful macros in the file `surfaces`; say \texttt{load surfaces} to read them. If \texttt{VERBOSE} is one or more, a helpful header will be printed when you load the file.

---

\textbf{Syntax:} \texttt{TABLE \[subtable\] \['format'\] file}

\texttt{TABLE subtable \n}

\texttt{READ TABLE \{ \texttt{WORD} \[\texttt{WORD} \ldots] \}}

\texttt{READ TABLE 'format' \{ \texttt{WORD} \[\texttt{WORD} \ldots] \}}

\texttt{READ TABLE 'byname' \{ \texttt{WORD} \[\texttt{WORD} \ldots] \}}

\texttt{READ TABLE 'bycolumn' \{ \texttt{WORD id} \[\texttt{WORD id} \ldots] \}}

\texttt{LIST TABLE}

SM is able to read a wide range of table formats, using tricks similar to those used for the \texttt{IMAGE} command. The variable \texttt{table_type} is used to specify which you want (and may be set in your `.sm` file). Common values are \texttt{bintable} and \texttt{ctable}.

\texttt{TABLE \[\ldots\] file} is the equivalent of the \texttt{DATA} command, and sets \texttt{file} to be the source of data read with the \texttt{READ TABLE} command; if the file can't be opened for read, you will be warned. If the \texttt{subtable} argument is provided, it specifies which table in a \texttt{TABLE} file is to be read; this is only currently supported for FITS tables ($\texttt{table_type}$ is \texttt{bintable} or a type derived therefrom; for such tables you probably want to use a subtable of 1). The format, if provided, specifies the types of the columns in the table; some tables may provide this either in the table header (e.g. FITS binary tables) or in the filecap file, as the \texttt{FM} quantity. Allowable format strings are specified at the end of this file. This format applies to \texttt{READ TABLE} commands for this table, unless specifically overridden.

The range of lines specified by \texttt{LINES} is reset; the \texttt{LINES} command may be used to select portions of \texttt{TABLEs} to read.

If you don't specify the filename, and if SM knows how to skip tables, it will skip over HDUs that it has already read, provided that the SM variable \texttt{save_read_ptr} is set (which it is by default; see (undefined) [Read], page (undefined)).

The \texttt{READ TABLE} command is used to read data from a table. If you specify a format string and a list of names, a vector will be read from each column specified in the format and assigned to the corresponding vector (for example, \texttt{READ TABLE 'x16if2' \{ i x y \}} will skip 16 bytes at the start of the row, then read an integer into \texttt{i}, and two columns of floats into \texttt{x} and \texttt{y}). Format strings are described at the end of this section.

If you specify the format as `'byname'`, the names of the vectors will be taken to be the names of columns in the file, and the corresponding columns will be read. If the column name, say \texttt{RDL}, specifies an array, the vector will be filled from column \texttt{RDL[0]}; as an alternative to this you can
specify the name as (e.g.) RDL[2] in which case vector RDL2 will be created from column RDL[2].
You can also say RDL[0-2] to read vectors RDL0, RDL1, and RDL2. Byname access is only currently supported for FITS binary tables (as a special case, you can specify byname as the format in a filecap file).

The name that you give will be used as the name of the vector, but the matching with the binary table is done without regard to case, so

```plaintext
read table 'byname' { AlGoNqUiN }
```

and

```plaintext
read table 'byname' { Algonquin }
```

will read the same column of the table into two different vectors, AlGoNqUiN and Algonquin.

For tables where byname formats are acceptable, you can list the available column names with LIST TABLE.

If you specify the format as 'bycolumn', the list is expected to be a list of pairs of values (similar to the regular READ { x 1 y 2 ... } command). The first element of each pair is the name of a vector, the second may be either a number or a column name (if supported). The number gives the desired column with respect to the current format string. For example,

```plaintext
TABLE 'd*' file
READ TABLE 'bycolumn' { x 1 y 2 }
```

will read x and y from the first two columns of the file, whereas

```plaintext
TABLE 'x8d*' file
READ TABLE 'bycolumn' { x 1 y 2 }
```

will read x and y from the second and third columns of the file, assuming that a double (the d) is eight bytes wide.

Instead of a number, you may be able to specify a column name, for example

```plaintext
READ TABLE 'bycolumn' { x_u rowc[0] x_g rowc[2] }
```

but this depends on your chosen $table_type having support for byname access. In general you will not be able to mix name- and column- orientated access (for example, we do not support column orientated access to FITS binary tables unless you provide a format).

TABLE’s formats are strings (i.e. they must be enclosed with “”). consisting of a set of types followed by optional repeat counts, for example ‘x12f5d*’ would specify a table, each of whose rows had 12 unwanted bytes, 5 floats, and the rest integers. Format letters are:

- **a** A 1-byte ascii string
- **c** A 1-byte char
d An 8-byte double
f A 4-byte float
i A 4-byte int
l A long int (may be 8 bytes on some machines)
s A 2-byte int
x 1 byte to skip (a space may be used instead of an x)

and each may be followed by a repeat count (default: 1), or a *, meaning to repeat as many

times as fits into a row. In all cases except a, the repeat count refers to how many columns there

are (so d4 means 4 doubles); for a it refers to the length of the string (so a4 is one 4-byte string).

Note that the maximum length of an a table is the length of an element of a string-valued vector

(usually 40, but configurable by whoever built your copy of SM).

Header keywords may be available with the DEFINE name IMAGE command.

Syntax: TERMTYPE word [ INTEGER ]

Set the terminal type to be WORD. This has nothing to do with graphics, but is to do with

the history and macro editors. WORD is case-sensitive. With two exceptions, the properties of the

terminal will be read from the termcap file (see (undefined) [Termcap], page (undefined)). If WORD

is dumb SM tries to support editing on a (very) stupid terminal. If this isn’t what you want, for

example you are running SM from within emacs TERMTYPE none is equivalent to starting SM with

the -s flag and entirely disables input line editing (although commands are still remembered so

commands like playback and hcopy will still work). You can turn editing back on by issuing a

TERMTYPE command with a valid terminal name.

For most purposes you don’t even need to use this command, as when SM starts up it reads the

value of the environment variable TERM (under Unix) or logical variable (under VMS) it effectively

issues a TERMTYPE command with its value as argument. If you have a term entry in your ‘.sm’

file this takes precedence over any TERM variable. For example, a term entry of selanar -21 is

equivalent to the command TERMTYPE selanar -21.

You also should not have to use the optional INTEGER argument, which specifies the number of

lines that will appear at a time when LISTing things, as this information is usually derived from
termcap. If you are using a window system, then termcap may be wrong and this argument may
be useful. Another exception occurs when you wish to disable cursor motion to avoid having your

graphs scrolling off the screen. If this concerns you see (undefined) [Termcap], page (undefined).

Syntax: TICKSIZE SMALLX BIGX SMALLY BIGY
Determine tick intervals for BOX. SMALLX refers to the interval between small tick marks on the x axis, BIGX refers to the interval between large ticks and so forth. If BIG is 0, the axis routine will supply its own intervals according to the label limits. If SMALL < 0, the axis will have logarithmic tick spacing and BOX assumes that the limits are logarithms, e.g. -2 and 2 refers to limits of 0.01 and 100. If both BIG and SMALL are 0, you’ll get SM’s default behaviour.

Negative values of SMALL and BIG are interpreted as specifying the tickspacing in the decade 1:10, and are scaled to fit the decades actually plotted. For instance, if you say

```
LIMITS 0 1 3 4
TICKSIZE -1 10 -0.1 1 BOX
```

then the x-axis will have small ticks at 2, 3, ..., 9 and big ticks at 1 and 10, while the y axis will have small ticks at 1100, 1200, 1300, ... and big ticks at 1000, 2000, 3000, ... (You might want to use NOTATION to stop SM using exponential notation for the 10000 label). The most usual TICKSIZE is probably \(-1\ 10\), and this may be written \(-1\ 0\) for backwards compatibility.

Occasionally you may want to use the same tickspacing in all decades of your plot. To do this make BIG negative also in which case the spacing used for the first decade plotted will be used for all decades. (Note that this means that if the axis is plotted backwards then the value from the largest decade will be used):

```
LIMITS 1.9 2.1 2.1 1.9
TICKSIZE -0.1 -1 -0.1 -1 BOX
```

this is a good way to make an axis very crowded!

If you really cannot use TICKSIZE to accomplish your needs, you can use AXIS and provide vectors specifying the positions of the big and little ticks, and even the axis labels.

Syntax: USER ABORT [ string ]
USER integer string

The first form, USER ABORT, is used to generate a syntax error, and return to the prompt (with a traceback if you’ve requested one with the traceback variable). The command reported as the offender is string if provided, otherwise USER ABORT.

If you want to catch these errors you can define a macro abort_handler which will be called with the message as all of its arguments instead of causing SM to return to the command prompt. For example, I use

```
abort_handler 111 # catch USER ABORT
  echo Caught user abort: $1
```

Note that the argument extends to the end of the line — this is important! If abort_handler took a single argument, what would the command USER ABORT good bye world do? First the
handler would be called as `abort_handler good bye world'. It’d pull off the first argument `good' and print it and SM would continue to process `bye' as a command. It’s neither a command nor a macro, so the default `macro_error_handler' executes `USER ABORT bye is not a macro; aborting'.

Rest of line: `world'. The abort handler pulls of the `bye', and tries to execute `is' — and we have an infinite recursion that is broken only by a ^C or by reaching the maximum depth to which SM will nest abort handlers.

The other, with an integer, calls a function called `userfn', passing the `integer' and the string as arguments, both are passed by address as if SM were written in fortran (string is passed as a NUL terminated C string, though).

This function is provided to allow users without C compilers to make additions to the main grammar, but whether it is really useful is a different matter. Currently, if `integer' is non-zero then both `integer' and `string' are printed unless `integer' is 1, in which case the command `USER 1 r 1.23' is equivalent to `SET r=1.23' (only constants are allowed).

If `string' is `dump' you’ll get a macro stack trace, and if it’s `segv' you’ll get a segmentation violation (on purpose). If you really want some new functionality, send us mail.

Syntax: VERBOSE INTEGER

Make SM produce output on what it is doing if `integer' is > 0. Setting VERBOSE to 0 is a way of only listing ‘important’ (non-system) macros, and generally getting a little peace and quiet. It has the considerable disadvantage that you can think that you are reading data from files, while actually something is wrong. For this reason the default value is 1. A value of 2 or more is basically useful for debugging. If you get some nondescript syntax error and don’t know where it is coming from, VERBOSE of 3 or 4 will trace your programme, and should help find the problem. The original error message will tell you which macro SM thinks it is processing when the error occurred but it will be wrong if the macro had been fully scanned when the error is detected. In this case it will report a parent of the current macro. The reason for this behaviour is related to why `RETURN' can return from the wrong place (see `undefined' [Command Internals], page `undefined').

If you want to know the current value of VERBOSE you can use the SHOW command (actually a macro), or try

DEFINE verbose DELETE echo Verbose: $verbose

which is (of course) what SHOW does anyway.

If `verbose' is one or more SM will:

- Complain about things like division by zero, and logs of negative numbers the first time that they occur in a given expression
- Identify the X11 device that you switch to with `-dev [+-]`

VERBOSE
• Include all macros in macro listings, even those starting ##
• Indicate line where arithmetical errors occur
• List all non-printing key-bindings with LIST EDIT
• Note more than 40 curve crossings in SHADE
• Notify user when a CONTROL-C stopped the production of a hardcopy
• Output a little extra about RESTORE and SAVE
• Print lines beginning # while reading macro files
• Provide some context with APROPOS on help files
• Realise that a WINDOW number is out of range
• Report which lines are read from a file using READ
• Remind you that mixing LOCATION with WINDOW confuses people
• Say something about format and size of IMAGE files
• Suggest that you change LOCATION to make room for axis labels
• Tell you what keys to use with the cursor
• Warn about zero-length vectors
• Whinge about missing fields with DEFINE var READ # #
• Write a note when it finds out-of-range values while contouring IMAGE files

if INTEGER is two or greater, then also :
• Announce when the do, foreach, input, or macro stacks are extended
• Complain if an environment or SM variable is not defined
• Echo lines in data files that start with #
• Include ‘internal’ variables in LIST DEFINE output
• Inform you when it seeks to a line in a data file
• List all key-bindings with LIST EDIT
• Note attempts to ‘unput’ off bottoms of buffers (this is related to the implementation of macros and variables)
• Point out attempts to delete local variables and vectors
• Print the fraction of axes covered by the tick labels
• Prompt for variables, even if they are on the macro buffer
• Protest if you reference an undefined history number
• Remark if a variable is referenced in a graphcap SY string, but not provided
• Remind you that only a finite number of KEY commands can be processed
• Repeat complaint about things like division by zero, and logs of negative numbers every time that they occur

VERBOSE
• Report vectors of different lengths in PRINT
• Say when a vector is used as a scalar.
• Tell you when vectors are redefined.
• Write a note when it finds out-of-range values while contouring IMAGE files.

if INTEGER is three or greater, then also :
• List each macro name just prior to expansion.

if INTEGER is four or greater, then also :
• Print each token as it is recognised along with its text. The number in column 1 is the value of ‘noexpand’, the level of nesting of {} loops.
• Show expansions of variables.

if INTEGER is five or greater, then also :
• Print the contents of DO, FOREACH, IF, and MACRO command lists.
• Prompt for DEFINEing variables and the values of multi-word variables.

If you set a negative verbosity, then if the parser was compiled with DEBUG defined, you’ll get a veritable torrent of debugging information. Use another negative VERBOSE command to turn it off again.

Syntax: VERSION

Return a string identifying the version of SM in use. If you have any reason to communicate with SM’s authors, we’ll want to know which version you are running. As a matter of fact, version is a macro to print $version.

Syntax: VIEWPOINT theta phi l

Surfaces are drawn from a direction (THETA,PHI), and projected onto a surface passing through the origin. The projection is from a point L away from the nearest corner of the cube containing the image. If L is positive a perspective projection is used; if it is 0 the viewpoint is taken to be infinitely far from the surface, and if it is negative an axonometric projection is used (i.e. the surface is projected from infinity onto the x-z plane).

The coordinate system is such that the z-axis is \textbf{THETA=90}, the x-axis is \textbf{(THETA,PHI) = (0,0)}, and the coordinate system is right handed. Angles are taken to be in degrees, with theta lying in [-90,90] and phi lies in [-180,180]. The nearest corner of the cube containing the surface is projected onto the point (0,0).

\textbf{VIEWPOINT}
There are some useful macros in the file `surfaces`; say `load surfaces` to read them. If VERBOSE is one or more, a helpful header will be printed when you load the file.

Syntax: Whatis ( expr )

WHATIS(something) has a value depending on what something is:

<table>
<thead>
<tr>
<th>Type</th>
<th>Bit(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a number:</td>
<td>0</td>
</tr>
<tr>
<td>not a number:</td>
<td>set 01 bit (bit 0)</td>
</tr>
<tr>
<td>a macro:</td>
<td>set 02 bit (bit 1)</td>
</tr>
<tr>
<td>a variable:</td>
<td>set 04 bit (bit 2)</td>
</tr>
<tr>
<td>a vector:</td>
<td>set 010 bit (bit 3)</td>
</tr>
<tr>
<td>a float vector:</td>
<td>set 040 bit (bit 5)</td>
</tr>
<tr>
<td>a string vector:</td>
<td>set 0100 bit (bit 6)</td>
</tr>
<tr>
<td>a long vector:</td>
<td>set 0200 bit (bit 7)</td>
</tr>
<tr>
<td>a keyword:</td>
<td>set 020 bit (bit 4)</td>
</tr>
</tbody>
</table>

So if “aa” is the name of a string vector, WHATIS(aa) has the octal value 0111, or 73, whereas WHATIS(HELP) has the value 021, or 17, and WHATIS(1) is 0. There is a macro in ‘utils’ called is_set that tests if WHATIS sets a particular bit, for example

```bash
if(is_set(kkk,3)) { echo kkk is a vector }
```

tests if bit 3 (vector) is set for “kkk” and prints its findings; it’s easier to say

```bash
if(is_vector(kkk)) { echo kkk is a vector }
```

which does the test for you.

Syntax: WINDOW nx ny x y

WINDOW makes the current plot location the window at (x,y), where there are nx windows across and ny windows up and down. WINDOW 1 1 1 1 resets the plot location to the entire plot area. The size and placement of the windows is decided by the value of EXPAND when the WINDOW commands are issued, so be sure that EXPAND has the same value for every window in a set. (It’s used to figure out the axis labels, and spacings between boxes). While plotting to a given window you can of course change EXPAND to your heart’s content.

If the number of windows in either the x or y direction is negative no space is left between the boxes in that direction (try DO i=1,3 { WINDOW 1 -3 1 $i BOX }). It’s possible to overload ‘window’ and ‘box’ to only label external axes in blocks of touching boxes.

If either x or y is specified as, e.g. 2:4, the window is set to cover the range 2-4 (i.e. the part of the screen covered by windows 2, 3, and 4). Note that this feature can be used to split the screen in arbitrary ways, e.g.

WINDOW
window -1 -6 1 1:5 box
window -1 -6 1 6 box

(or you could say window -20 -20 15:19 15:19 as an alternative to a LOCATION command).

If you don’t want boxes that touch, but you don’t like the gaps left between boxes by the WINDOW command, you can now do something about it legally, without lying to SM. After we calculate the widths of the ‘gutters’ between the windows that we think that you need, they are multiplied by the values of the SM variables x\_gutter and y\_gutter, so if you think that the spacing is too large in the x direction you can say

```
define x\_gutter 0.5
window 2 2 1 1 box
window 2 2 1 2 box
```

to make things look better. Within a macro it can be convenient to say local define x\_gutter 0.5, as then the gutter value softly and suddenly vanishes at the end of the macro.

It’s confusing to change LOCATIONs while using WINDOWs; you probably want to say WINDOW 1 1 1 1 first.

```
Syntax: WHILE { expr } { commands }

Repeat the commands while the expr is true. You can break out of the loop early with the BREAK command (see \h{Break}, page \h{Break}).

There is further discussion in section See \h{Loops and If}, page \h{Loops and If}.

For example,

```
define i 0
while{$i < 10} {
    echo Hi $i
    define i ($i+1)
}
```

is equivalent to either

```
do i=0,9 {
    echo Hi $i
}
```

and

```
set i=0
while{i != 100} {
    if(i == 10) { break }
    echo Hi $(i)
    set i=i+1
}
```

WHILE
except in so much as which variables and vectors are defined at the end.

**Syntax:** WRITE STANDARD string  
WRITE [+] WORD string  
WRITE HISTORY WORD

WRITE STANDARD writes a string, followed by a newline, to the standard output. The string is taken to be the rest of the line up to a carriage return (which may be written explicitly as \n). The macro `echo` is usually used as an abbreviation for this command. WRITE WORD is similar, except that the string is written to file `WORD`. If the filename is the same as the previous WRITE, or if you preface the filename with a +, the string is appended, otherwise the file is overwritten.

WRITE HISTORY WORD, writes macro `WORD` onto the end of the history list.

For MACRO WRITE, see under macros.

**Syntax:** XLABEL str

Write the label `str` centered under the x axis made by BOX. The string is taken to be the rest of the line up to a carriage return (which may be written explicitly as \n). If you think that the label is badly positioned you can say things like

`XLABEL \raise-500My X-axis Label`

(providing that you use TeX-style fonts, of course)

If the label is too tall it may overlap with the numerical tickmark labels. If VERBOSE is one or more, you’ll be warned about this, and a suggested change to the plot LOCATION will be suggested. This moves the entire plot; it is your responsibility to reset it later if appropriate.

If ANGLE is non-zero, it will be used to determine the direction of the label, otherwise it is parallel to the x axis.

See (undefined) [Labels], page (undefined), for a description of how to enter a label with funny characters, sub- and super-scripts, and so forth.

If EXPAND is set to exactly 1, and ANGLE is exactly 0, then SM will use hardware fonts, when available, in writing labels. This is faster, but if you don’t like it say “EXPAND 1.00001”, or start the string with a \0 which does nothing, but forces the software character set.

**Syntax:** YLABEL str

Write the label `str` centered to the left of the yaxis made by BOX. The string is taken to be the rest of the line up to a carriage return (which may be written explicitly as \n). If you think that the label is badly positioned you can say things like

`YLABEL`
YLABEL \raise500My Y-axis Label

(providing that you use TeX-style fonts, of course)

If the label is too tall it may overlap with the numerical tickmark labels. If VERBOSE is one or more, you’ll be warned about this, and a suggested change to the plot LOCATION will be suggested. This moves the entire plot; it is your responsibility to reset it later if appropriate.

If ANGLE is non-zero, it will be used to determine the direction of the label, otherwise it is parallel to the y axis (ANGLE 360 will achieve horizontal labels).

See (undefined) [Labels], page (undefined), for a description of how to enter a label with funny characters, sub- and super-scripts, and so forth.

If EXPAND is set to exactly 1, and ANGLE is exactly 0, then SM will use hardware fonts, when available, in writing labels. This is faster, but if you don’t like it say “EXPAND 1.00001”, or start the string with a \0 which does nothing, but forces the software character set.
Appendix A  Appendices

A.1 The Command Interpreter

The basis around which the command interpreter is written is a grammar which is passed a set of tokens (analogous to words in English) which it parses, given a set of grammatical rules. As it recognises each rule, it executes the code associated with that rule. See (undefined) [Grammar], page (undefined).

An example would be:

```c
aa : BB CC
{
    printf(``Rule BB CC found\n'');
}
```

which specifies that the rule aa consists of the token BB followed by CC, and that if rule aa is recognised the programme should print that fact out. Conventionally, uppercase names are reserved for ‘terminal symbols’, and lowercase for ‘non-terminal symbols’ where terminal symbols are those that are passed to the parser (analogous to words), and non-terminal symbols are tokens that the parser has constructed out of terminal symbols (analogous to phrases). The right hand side of a rule may contain a mixture and non-terminal symbols, and symbols may be assigned a value.

A.1.1 Token Generation

SM generates tokens for the grammar roughly as follows: When characters are typed at the keyboard, they are read by a routine which runs in CBREAK mode (PASSALL for VMS), and receives each character as it is typed. It is this routine that handles command line editing, the history system, and key bindings. Following a carriage return, it passes the whole line to the lexical analyser, which divides the input stream into integers, noats, strings, or words. In addition it recognises `^'' as having special meanings (see below under variables (${}) and history (^)). As in C, the escape sequence `\n' is replaced by a newline, which means that commands which read to the end of the line may be fooled into thinking that they have found it; see the examples at the end of the section. A `{ sets the flag `noexpand', which turns off the interpretation of all special symbols,

---

1 The grammar is actually specified using YACC, see S.C. Johnson YACC: Yet Another Compiler Compiler, Computing Science Technical Report No. 32, 1975, AT&T Bell laboratories, Murray Hill, NJ07974. This report is reprinted in section 2b of the UNIX manual, and is rather difficult reading at first. We do not in fact use the AT&T code, which is proprietary, but rather a public domain compiler-compiler called Bison written by the Free Software Foundation.

2 Specifying `-s` on the command line bypasses all of this, and makes SM read input one line at a time.
and causes all tokens to be returned as `WORD`. The matching `}` unsets this flag. This mechanism is used in defining macros and various lists. A word is anything which is not otherwise recognised, so for example `hello there.c` or `1.2e` would be considered words. Symbols are separated by white space, taken to be spaces tabs or newlines, or the characters !, {, }, +, -, *, /, =, ?, !, ,, <, >, (, or ) . This behaviour can be modified by enclosing a string in double quotes, when no characters (except ^) are special, and tokens are delimited only by the end of the line, or some character after the closing quote. Enclosing in quotes is rather similar to enclosing in {}, except that quotes have no grammatical significance. A string in double quotes is always treated as a word, but the quotes must not have been discarded by the time that the lexical analysis occurs. For example, "2.80" is a float, as SM will have digested the " before looking at the string. You can fool it with "2.80 ". A string begins with a ' and continues to the next ': they are used in certain contexts where SM needs to know if a `WORD` or `STRING` is involved, for example in a `PRINT` command. It’s worth noting that the '...' are stripped when the string is recognised — if you need to preserve them make sure that `noexpand` is set (e.g. `SET s={ 'a' 'b' 'c'}`).

The output from this programme is passed to a second stage of lexical analysis. This passes integers and floats through unaltered, while words are passed through a filter to see if they are external tokens\(^3\) from the grammar (such as `CONNECT`). If a word is recognised as being a token then that token is returned, otherwise the token `WORD` is passed, and the text of the word is stored. Tokens may be written in either lower or upper case, but for clarity they are written in upper case in this document. The overloading of lowercase tokens is achieved at this stage by simply refusing to recognise them as keywords.

The input stream is now fully analysed into tokens and is passed to the parser, which is written in YACC. If the sequence of tokens seen corresponds to a grammar rule, the parser executes the appropriate section of code, which is written in C. If the parser doesn’t understand, it tells you that you have a syntax error and prints the last logical line that it was processing, with the error underlined. If you can’t figure out which command it really failed on, try setting the `VERBOSE` flag to be 4 or more. This produces a voluminous output, which will stop suddenly when the error re-occurs. One simple rule in the grammar is that a `WORD` should be treated as a possible macro.

\(\text{A.1.2 Peculiarities of the Grammar}\)

If the command interpreter is faced with a pair of grammar rules such as

\[
\begin{align*}
\text{AA BB CC} \\
\text{and} \\
\text{AA BB}
\end{align*}
\]

it may not know whether to treat the tokens `AA BB` as the first part of `AA BB CC` or as the complete command `AA BB` followed by the token `CC` beginning the next command without examining the next

\(^3\) i.e. tokens that have been recognised, typically keywords
token. This ambiguity only arises if a command can begin CC, and may be dealt with by defining the second rule as

```
AA BB \n
```

This should be borne in mind whenever SM complains about a syntax error in an apparently valid command (such as LIST MACRO HELP, intended as first LIST MACRO and then the valid command HELP). The presence of a required carriage return also sometimes requires that macros be spread over a number of lines rather than as one long list of commands, although a carriage return may always be written as `\n', which makes SM think that it has found a carriage return. There is also a requirement that an ELSEless IF statement should end with a newline; this is produced by a subtlety of the way that IF's are processed and is discussed under IF.

SM places a restriction upon commands such as RELOCATE which expect more than one argument, which is that the arguments must be numbers rather than (scalar) expressions. This is required by the unary minus, as if the grammar sees expr1 - expr2 it cannot know whether this is the two expressions expr1 and -expr2, or the single expression expr1-expr2. Unless the grammar is changed, for instance by using commas to separate arguments, this restriction cannot be lifted; it can, however, frequently be circumvented using macros such as rel discussed under ‘Useful Macros’. As an alternative, in almost all cases the expression can be enclosed in parentheses, for example connect (lg(x)) (-lg(rho)).

### A.1.3 The Macro Processor

Executing a macro consists of substituting the text of the macro for its name. In order to understand how SM does this you have to know a bit more about how it processes input characters. We said above that it ‘passed the whole line’ to the lexical analyser. What it actually does is to pass a pointer to the line, and starts reading from the beginning of the line. Now if you execute a macro, all that is done is that we now pass a pointer to the text of the macro, and start reading from it instead. The old pointer is pushed onto the top of a stack. When SM comes to the `\n' at the end of the macro text, the stack is popped and input continues as if the macro had never been seen. When we come to the end of the ‘whole line’ pushed at the top of this paragraph, it is popped, and SM gives you a prompt for more input. Of course, if a macro had been seen while the first macro was being executed, the first one would get pushed onto the stack, and attention transferred to the the new one. If a macro has any arguments, their definitions are pushed onto an argument stack which is popped at the proper times. To jump ahead a little, variables are implemented in a very similar way, being pushed onto the stack, as are DO and FOREACH loops, and perhaps more surprisingly IF statements.

The strange behaviour of RETURN at the end of macros comes about because when the input routine is reading the RETURN it has to read one character beyond it, so as to know that it isn’t dealing with, say, RETURN_OF_THE_NATIVE. But in looking for the next character it has to pop the macro off the stack, so when the RETURN is acted upon we have already returned from where we
wanted to return from, and we now RETURN from the wrong place. In a similar way, an IF at the
end of a macro will cause the parser to look for an ELSE, thereby popping the macro stack if there
isn't one. If the IF test was true, and contained references to macro arguments, there will be a
problem as either there will be no macros defined, or the arguments to the previous macro on the
stack will be supplied.

This behaviour is changed in SM2.4.3 and above; an automatic space or newline is added at the
end of every macro, avoiding this problem.

Macro definitions are currently stored in the form of a weight-balanced tree (actually a BB\(1 - \sqrt{2}/2\) tree). This means that the access time for a given macro only grows as the logarithm of
the total number defined. In the future it may be possible to choose the weights depending on the
access probability for a given macro, but this is not currently possible. Definitions of variables and
vectors are stored in the same way.

A.1.4 The DO, FOREACH, and IF commands

It seems worth discussing the implementation of these commands. Both loops consist of a
definition of a variable, together with instructions about what to do with it, followed by a list of
commands within a set of \{\}, while IF just has the command list. It is not possible for the main
grammar to execute commands or macros, as the YACC implementation is non-reentrant, so the
best that it can do is to push the commands onto the input stack as a sort of temporary macro,
after defining the initial value of the loop parameter. When the `\0' at the end of the loop appears,
instead of popping the macro stack we simply define the loop parameter to have its next value, and
jump back to the beginning. This means that you can't change the value of a loop parameter, as
it'll be reset anyway, but you can use it as a sort of local variable.

IF statements are similar, in that we read the entire list before executing it. Once more, a
temporary buffer is pushed onto the stack, with instructions to delete it after use. The reason that
a newline is required after an ELSEless IF is that the grammar will have already read the next
token to see if it was ELSE. If it wasn't, then it will seem to have been typed before the body of
the IF. For example, IF( test ) \{ echo Hello \} PROMPT : will be parsed as IF( test ) \{ PROMPT
echo Hello \} : if test is true, but correctly as IF( test ) \{ echo Hello \} PROMPT : if it is false.
Because an extra \n does no harm, we demand it.

A.1.5 Examples of How SM Parses Input

If you want to watch SM thinking about these examples, the command VERBOSE 4 will make
it print out in detail each token as it reads it, and each macro or variable as it expands it. To
turn this off, use VERBOSE 0 or VERBOSE 1. To really see the parser at work, try a negative value
of verbosity. This will report every step that the parser takes, providing that it was compiled with
DEBUG defined. A second negative value will turn the information off again.
PROMPT @  PROMPT is an external token, so PROMPT is passed to the grammar which recognises the rule PROMPT WORD, and sets the prompt to be '@'. When it has finished, control is passed back to the input routine.

MACRO p { PROMPT }
This is a simple macro defining p to be PROMPT

p @  The lex analyser doesn’t recognise p as a keyword, so it returns WORD and as the grammar has no other interpretation of a WORD in this context, it passes p to the macro interpreter, which replaces it by PROMPT (i.e. pushes PROMPT onto the input stack). SM now thinks that you have just typed PROMPT @, and behaves as described in the first example.

MACRO pp 1 { PROMPT $1 }
The macro pp is declared to have one argument, which is referred to as $1. After pp is invoked it reads the next (whitespace delimited) word from the input stream, and replaces $1 by that word.

pp @  Just like the first example, the prompt is set to @.

pp  You are prompted for the missing argument to PROMPT.

PRMPT  As PRMPT isn’t an external token, it is a WORD, so SM tries to execute it as a macro and complains if it isn’t defined.

DEFINE Hi Hello
The variable Hi is defined to have the value Hello.

WRITE STANDARD $Hi Gentle User
When it has read $Hi SM pushes the value of the variable Hi onto the stack and then reads it, popping it off again when it has finished. The WRITE STANDARD command writes Hello Gentle Reader (i.e. up to the end of the line) to the terminal.

WRITE STANDARD $Hi Gentle User \n pp "SM>"
As above, the rest of the line is written to the terminal (up to the carriage return ‘\n’), then the prompt is changed yet again.

A.2 The Stdgraph Graphics Kernel

SM can use a single set of subroutine calls to plot on almost any terminal, and on many printers. The routines that it uses, called stdgraph, were originally taken from the IRAF GIO package written at Kitt Peak by Doug Tody⁴ and converted to C and partially re-written to be integrated into SM. Despite our extensive rewrite, these routines should probably still be considered to be in the public domain.

⁴ Graphics I/O Design, Doug Tody, March 1985. NOAO (Kitt Peak)
A.3 The Graphcap File

Stdgraph uses a file called a graphcap file to specify the properties of terminals, in a way that is similar to the termcap facility of Unix. You don’t have to know anything about termcap to read this section; you don’t have to read this section unless you want to change the graphcap file to add a new device, to fix a bug, or to change the way that SM treats your plotting device. The name of the graphcap file is given by the variable `graphcap` in the environment file.

A list of files to be searched in order may be given instead of a single graphcap file (up to a current maximum of three). The usual way to accomplish this is to add an entry

```
+graphcap /u/rhl/sm/graphcap
```

above any other graphcap entries in your `.sm` file, which instructs SM to put `/u/rhl/sm/graphcap` first in the list of files, followed by any others that might appear, either in your file or in some other that the system provides (ask the person who installed SM where the default `.sm` file is; usually something like `/usr/local/lib/.sm`).

A graphcap file is a way of describing a terminal in a concise way, so a programme can discover which idiosyncrasies a terminal has without having to be recompiled. A graphcap file consists of a number of entries, one for each device supported, and to add a new terminal all that one has to do is to add another entry. It is also possible to define variables in graphcap files, which are used in SY entries. You can compile selected entries in the graphcap file, so as to improve access time for popular terminals. If this has been done, changing the graphcap file for one of these terminals will have no effect until it is recompiled, see [Compiling], page (undefined) for details.

For a list of all the capabilities that SM uses see the index to graphcap at the end of this appendix.

Some devices are not supported through stdgraph (graphics drawn to a SunView window would be an example), but they still appear in graphcap with a special entry (DV) giving the name of the appropriate hard-coded device driver.

Each entry consists of a name for the device, followed by a list of aliases, followed by a list of fields, separated by colons. A \ may be used to continue an entry onto the next line, and lines starting with a # are comments (comment lines are permitted both between and within entries).

As a rather complex example, the graphcap entry for a Tektronix 4012 reads:

```
+graphcap /u/rhl/sm/graphcap
```

```
tek4010|tek4012|TEK4010|TEK4012|Tektronix 4010/2:


This is one of the longest entries in the graphcap file - all of the terminals which are Tektronix emulators explicitly include this entry, so they only need provide the capabilities that are different from the Tektronix. As an example, the entry for a Pericom reads

```
pericom|Pericom:\n:GE=^]:TB=^]
:(2#7-!2)%t^_:
:tc=tek4012:
```

The | separate the aliases, and the final field tc=tek4012 tells stdgraph to take all other fields from the entry for tek4012, given above. If you have specified a list of graphcap files, each will be searched in order for each :tc= continuation. If you don’t want the search to begin again use TC, e.g.

```
graphon|Graphon which claims to support lw:\n:LW=:TC=graphon:
```

if you had used :tc=graphon: this would have been recursive and illegal, but as TC doesn’t restart the search it merely has the effect of adding (or in general, replacing) an capability in a preexisting graphcap entry.

Control characters are entered as `^A, `^B, and so on (those are two characters, `^' and `A'). ‘Escape’ may be represented as `^[, `\E, or in octal as `\033. Because the normal way of handling strings in C treats ‘\0 as meaning ‘end of string’ you can’t simply put a ‘\000 into a graphcap entry, instead write ‘\377 and SM’ll interpret it as ‘\0. (If you need a real ‘\377 enter ‘\377\377). If a delay of so many milliseconds is required before the transmission of a string, it is given first (followed by a * if it is to be applied to each line affected). This leads to problems with graphcap entries that start with numbers, you must precede them with a space or (if the string is run through the encoder) insert a no-op e.g. :CP=()1000:. Numerical values are preceded by a #, so :co#80: means that co (the number of columns displayed) is 80, while :MC=\^M: means that MC (the cursor delimiter) consists of the character ‘^M. This could just as well have been written :MC=\010:. If the first character of a capability is ‘\0’, it specifies that that capability is not present for that terminal (e.g. :lt@=1234: specifies that lt is not defined). A field may simply not be provided if it is irrelevant, although in this case it may be supplied by a tc or TC continuation. A common set of graphcap entries to ‘comment out’ are TB and TE, which deal with hardware character sets. If you don’t want your plotter to use it’s internal fonts simply insert ‘\0 before the ‘=’. By inserting their private file before the system one in the list of graphcap files, users can tailor the entries to their liking.

We use a subset of the graphcap capabilities defined by the IRAF group, and the distinction between upper and lower case parameters comes from them. In a few cases our usage is different from theirs, in these cases we have specified our own capabilities (CD → MC, DD → SY, LT → ML, and TS → TB. We have also added the lt, BP, BR, CO, CS, CT, DC, DT, DV, EP, ER, and TC. capabilities.). First the lower case, which specify mostly dimensions:

ch       Height of a character, relative to the screen height being 1.0.
co       Number of columns displayable, with characters of width cw.
cw Width of a character, relative to the screen width being 1.0.
li Number of lines displayable, with characters of height ch.
lt Which linetypes are supported in hardware.
pc Pad character for delays (use NUL if not supplied).
xr x dimension of plotting device. This may be specified as an argument from the DEVICE line. E.g. for DEVICE example 1200 1400, :xr=$1:yr=$2: is equivalent to :xr#1200:yr#1400:
yr y dimension of plotting device. See the previous entry for an example.

Of these, co and li are not currently used.

The capitalised capabilities mostly tell the stdgraph routines how to plot lines, clear the screen and so forth. Some of these are no more than character strings to send to the terminal, (e.g. CL to clear a screen), but some use the grapcap entries to programme a sort of RPN calculator, which computes the bit-patterns that the terminals demand. This calculator is usually referred to as the ‘encoder’. We’ll first list all the capabilities in a reasonably ordered way, then describe the encoder and what it can do, and then go through a number of examples.

First the fields which are simple character strings to be written to the terminal. The second column is an attempt to explain the etymology of the two character name.

CL (CLear)
Clear the screen, possibly also the text screen.

CW (Close Workstation)
Close terminal, expect no more graphics.

DS (Draw Start)
Prepare the terminal to draw a line.

DE (Draw End)
Finish a line.

FD (Fill Draw)
Draw a side of a filled polygon.

FE (Fill End)
Finish drawing a filled region.

FS (Fill Start)
Start drawing a filled region.

GD (Graphics Disable)
Return the terminal to a character mode.

GE (Graphics Enable)
Set the terminal to graphics mode.
IF (Initialisation File)
   Used to supplement OW if sequence is too long.

LR (Load Registers)
   (Used by the RPN encoder, see ‘binary encoding’).

ME (Mark End)
   Finish a series of dots movements.

MS (Mark Start)
   Start a sequence of dots movements.

OW (Open Workstation)
   Prepare a terminal to produce plots.

OX (Open workstation)
   (a continuation of OW).

OY (Open workstation)
   (a continuation of OX).

OZ (Open workstation)
   (a continuation of OY).

PG (PaGe) Start a new page.

VE (? End)
   Finish a series of pen (beam) movements.

VS (? Start)
   Start a sequence of pen movements.

For hardcopy devices PG should start a new page. The GD and GE are used by terminals which spend some of their time being graphics terminals, and some being regular text terminals. The various “... Start” and “... End” capabilities assume that the points in question are specified by the XY entry (except for FS/FE where FD is used instead). Typically, the ‘start’ is used to put the device into (e.g.) line-drawing mode, then the line is drawn with a sequence of XY’s, then it is taken out of (e.g.) line mode with the ‘end’. The support for filling areas assumes that a region is specified by drawing a line around it; if this isn’t so, you’ll have to omit area fill from graphcap, and rely on SM emulating it for you. An example would be a Graphon GO-250, which has an area fill where you fill rectangular areas by specifying opposing corners; this is not acceptable to SM.

Some operations require an argument, for instance setting the hardware line type, specifying which cursor to read\(^5\), or specifying coordinates. In the following properties, the expected parameters are listed after the field names, the first to go into register 1, the second into register 2, and so on. If you haven’t skipped forward to the section on the encoder this will seem obscure, but all will become clearer.

\(^5\) Actually, SM always uses cursor 1
CO(r,g,b) (COlour)
   Set next colour to (r,g,b).

CS(n) (Colour Start)
   Start defining n colours.

CT(i) (Colour Type)
   Set a colour.

DC (Default Colour)
   Set default colour.

LW(f) (Line Weight)
   Set the lineweight to f.

MC(i,x,y) (sM Cursor)
   Decode a cursor response.

ML(i) (sM Line)
   Set the linetype to i.

RC(c) (Read Cursor)
   Read the cursor. ‘c’ is for compatibility.

SC (Scan Cursor)
   Decode the cursor reply following a RC.

TB(x,y) (Text Begin)
   Start writing text at (x,y).

TE (Text End)
   Stop interpreting characters as text.

XY(x,y) (X Y)
   Encode the coordinate pair (x,y).

Some of the above comments are a little cryptic, but we return to the various graphcap parameters that take arguments as examples after describing the encoder. Note that it isn’t sufficient to change the ML entry — for a linetype to be supported in hardware it must also be included in the lt list, e.g. lt=01234. Similarly, for hardware fonts you must include ch and cw, and TB must be present even if it does nothing. Note that LW is passed a floating point number, and that the special case 0 is special, meaning choose the most efficient line thickness for the device.

The following capabilities have to do with rasterising and are discussed in their own section near the bottom of this appendix:

BP (Bit Pattern)
   Bit patterns for rastered data.

BR(i) (Begin Row)
   Begin row of rastered data.
EP (Empty Pattern)
   Bit pattern for rastered empty pixel.

ER (End Row)
   End of a row in rastered data.

ll (LINE LENGTH)
   Length of a row for DR=hex.

MR (Many Rows)
   Number of rows output at once.

nb (NUM BYTES)
   Number of bytes to process at once for MR.

RA (RAster)
   (RA is no longer supported – see DV).

RD (Raster Device)
   Type of device if not generic.

   Raster devices also make use of xr, yr, CW, OW, OX, OY, OZ, OF, and SY which are also used by stdgraph itself.

   Finally there are some capabilities that are designed for driving hardcopy devices and devices that may not use stdgraph at all:

DT (Device Type)
   Type of device in use.

DV (Driver)
   Name of hard-coded driver.

OF (Out File)
   The file to direct output to.

RT (Record Terminator)
   (RT is no longer supported).

SY (SYstem)
   The action to be taken upon closing the OF file.

   The OF file may be specified with the last characters being ‘XXXXXX’, in this case the Xs are replaced by a random characters, to make a unique filename. If the variable temp_dir is defined in the environment file, then OF is created in that directory, otherwise it is put in the current directory. The DT string, if present, specifies the type of device in use. Currently the values are only used under VMS, where they are used to decide how to open files. The recognised values are “qms” and “imagen”. In general DT should be omitted, as it requires programming support, but it can help stdgraph to deal with hostile operating systems. For a discussion of the DV entry, See (undefined) [New Devices], page (undefined).
The SY string is passed to the operating system after graphcap variables have been expanded (they are similar to macros in Unix’s make). A variable is defined with a line like:

```
name = value
```

where name must start in the first column. Any white space surrounding the equals sign is removed, as are any trailing blanks. If value starts with a $ it is taken to be a regular SM variable. Variables may be defined in any of the graphcap files in the search path, and if a name appears more than once the first value found will be used (if you change graphcap without leaving SM the variables are re-read). There is no guarantee that all the graphcap files in the path will be read but this is unlikely to be a problem. The major use for graphcap variables is probably for encoding rasterise’s full name:

```
BIN = /usr/local/bin
device|some device:\
   :DV=raster:OF=tst_XXXXXX:\
...
:SY=${BIN}/rasterise -r $0 $F $1:
```

Variables are written as `${name}` not `$name`, which means that they will not (usually) conflict with the operating system’s uses for dollar signs. The graphcap variable F is special, as it always expands to the filename specified as OF. As a concession to history it may be written as `$F` instead of `${F}`. Also special are "$prompt", which is replaced by a string read from the keyboard (you are prompted with `prompt`), and `$n` which is replaced by the n’th argument to the DEVICE command. For example, if the DEVICE command were DEVICE qms lca0 Hello (or DEVICE 1 qms lca0 Hello), then the device name qms would be $0, lca0 would be $1 and Hello $2. If a ‘$’ is found under other circumstances it is simply treated as a dollar sign, but if you wish you can escape it with a \ (but remember that the \ must itself be escaped so to explicitly escape a dollar in an SY string you must type `\\$`). This means that (under Unix) you can access environment variables from SY strings, e.g.: SY=mv `${F}` $HOME:. If a variable is referenced but no value is provided when the device is opened a warning message is printed; this message can be suppressed by referring to the variable as (e.g.) `$\%1`.

The SY string is only used if an OF file has been specified. There is no guarantee that SY is supported by all operating systems, but it is certainly available under Unix and VMS (SY requires the C call ‘system()’, as defined for Unix. We have provided one for VMS, and any serious SM implementation would have to have one too.) A trivial example of SY in use on an Unix system would be:

```
:SY=cat $F ; rm $F:OF=out_XXXXXX:
```

(cat prints a file, ; separates multiple commands on a line, rm deletes a file). Because not all operating systems can support multiple commands on one line, you can use \n within a SY string to separate commands. For example, under VMS that SY string could have been written

```
:SY=type $F. \n delete $F..*:OF=out_XXXXXX:
```
(Type adds a `.lis' unless explicitly given a closing `.', delete requires a version number, hence the $F. and $F..*) An example of the use of "$" would be

:SY=mv $F "$Output filename? ":

which renames the OF file to whatever you want.

The RT capability has been deleted in version 2.0, in favour of using DT; The RA capability has been replaced in version 2.1 by :DV=raster:.

## A.4 Stdgraph’s Binary Encoder

Different terminals have very different ways of doing the same thing. For example to move the beam to (200,200), a vt240 in REGIS mode needs to be told `[200,259]', while a Tektronix 4010 needs `&h&H'. In order to cope with this much diversity, stdgraph has a binary encoder with a 50 element stack, 10 registers and about a dozen operators. The encoder communicates with the rest of the world through its registers - for example in encoding a coordinate pair it expects to find x in register 1, and y in register 2. When reading a graphcap string, initially stdgraph simply copies the input characters to an output string, which is then written to the terminal. This is exactly what it does when it interprets the OW string for a Tektronix, OW=^[^_]. However, in addition to characters such as ^ being special, it also recognises the following as being special:

` escape special meaning of next character
% Begin a format string
( Switch from copy into encode mode.

When in `encode' mode, the following operators are available:

` Escape next character (recognised everywhere)
% Formatted output, e.g. %d, %g, or %t
) Revert to copy mode
#nnn Push signed decimal number nnn onto the stack
$ Part of a switch statement
, Pop a number from the stack, and put it in the output string
, Get next number from input string, and push it onto the stack
'str' Prompt with str, then read a character and push it onto the stack
& Modulus operator (similar to an AND of the low order bits)
+ Add (similar to OR)
- Subtract (similar to AND)
* Multiply (a left shift if number is a power of 2)
/ Divide (a right shift if number is a power of 2)
< Less than (0:false, 1:true)
> Greater than (0:false, 1:true)
= Equals (0:false, 1:true)
;
Branch, <boolean><offset>; (; is at 0 offset)
0–9 Push register 0-9 onto the stack
!N Pop the top of the stack into register N.
!! Pop the stack, and delay that many milliseconds.
| Convert the top of the stack from float to int (it is rounded rather than truncated).

Unless otherwise specified the stack is taken to be integer-valued, although in fact it can support either integer or floating point values. There is no type checking – if you ask the encoder to print the top of the stack as a float, but you stored an int, you can expect trouble. If it is needed we might add more floating point support; apart from printing the top of the stack, the only floating point operation supported is ‘|’ which rounds the top of the stack (taken to be a float), converting it to an integer (so, for example, 1|1! converts the contents of register 1 from float to int).

All the binary operators operate on the top 2 elements of the stack, and push the answer onto the top. Any other character is interpreted as an integer, and pushed onto the stack - for instance, ‘is the same as ‘#64’, octal 100. A blank is the octal constant 040.

The % command means, ‘format the top of the stack, and write it to the output string’. The format string may be any printf format specifier (printf is the C formatted i/o function. In practice, the only formats that you are likely to need are %c, %d, %g and %t – and %t isn’t even in C! %c means ‘write the integer as a character’, %d means ‘format the number as a decimal integer’, %6d means ‘and make it fill 6 characters’, and %g means format a floating point number. If you should need to know more, look at any book on C.) The special format %t means ‘take x and y from registers 1 and 2, and format them for a Tektronix’. As we shall see below, you can programme the encoder to do this, but Tektronix emulators are so common that %t is provided for efficiency’s sake. In fact there are two Tektronics formats, %t for 10 bit addresses, and %T for 12 bit addresses. The switch and branch instructions are discussed below, while examining specimen ML and SC strings.

A.5 Examples of Graphcap Entries

As a simple example, the ANSI command to set a non-graphics cursor to a given line and column is
Assuming that the x and y coordinates are in registers 1 and 2 respectively, the corresponding graphcap string would be

```
"([(2)%d;(1)%dH"
```

(where the quotes are not part of the format.) What if line and column coordinates start at 1, but the terminal wants them starting at 0? then the format would be

```
"([(2#1-%d;(1#1-%dH"
```

You could write those #1's as `^A` which would be slightly faster, but why bother?

As promised above, it is also possible to encode Tektronix-type coordinates. The desired bit format for a 10-bit address is

```
0 1 ya y9 y8 y7 y6
1 1 y5 y4 y3 y2 y1
0 1 xa x9 x8 x7 x6
1 0 x5 x4 x3 x2 x1
```

where x1 is the least significant bit in x, and ya is the tenth bit in y. If x and y are in registers 1 and 2, the simplest XY (move/draw to (x,y)) string is

```
"%t"
```

but if this weren't available the following string would work:

```
"(2 / +.2 &+.1 / +.1 &@+."
```

(as before, the double quotes don't belong to the format). To understand this, First look up the octal values of ` ' (040), ` " ` (0140), and ` @ ` (0100). Then the first ` (' puts the encoder into encode mode. `2 /' pushes the Y value onto the stack, and right shifts it by 5 bits ( ` ' is 100000 in binary). The next ` +.' adds the resulting bit pattern `0 0 ya y9 y8 y7 y6' to 0100000 and transfers it to the output string, and we have produced the desired first byte. The other bytes are produced in a similar fashion.

As another example consider an AED512, which is reputed to desire the bit sequence

```
xa x9 x8 yb ya y9 y8
x7 x6 x5 x4 x3 x2 x1
y7 y6 y5 y4 y3 y2 y1
```

The graphcap string

```
"(#128!919/^N*29/+.19&.29&."
```

will accomplish this. We could further optimise this by loading the value `#128' into register 9 once and for all with the LR capability, so a part of the graphcap entry would appear as

```
":LR=#128!9:XY=(19/^N*29/+.19&.29&.:"
I've never seen an AED512, but this should work anyway.

The switch instruction has the form

$$i \ldots j-k \ldots l \ldots D \ldots$$

where $i$, $j$, $k$, and $l$ are integers. The encoder pops the top value off the stack adds ‘0’ to make it a character, and scans forward looking for a $\$$ followed by that character. $\$2-5$ would match the characters ‘2’, ‘3’, ‘4’, or ‘5’. When it has met its match, it executes the instructions that it meets until it reaches the next $\$$ in execute mode. The encoder then skips forward until just after the $\$$, and resumes scanning. If the character from the stack is not matched by any of the cases, the encoder will use the $D$ (i.e. default) case, if present.

As an example, consider how stdgraph sets the type of line to draw. SM expects linetype 0 to be solid, 1 to be dotted, and so on. We expect a linetype in register 1 and have to do something with it.

For a Tektronix, the linetypes are set by an ML entry:

ML=^[1(1$0)\'(1$1)a(1$2)c(1$3)d(1$4)b(1$$

What does this do? The ‘^[ is simple, it is executed in copy mode, and writes the character ‘^[ to the output string. The ‘[ enters encode mode, and places the contents of register 1, the desired linetype, on the stack. Then begins the switch. If the linetype is 0, then the encoder scans past the $0$ and starts reading the string again with ‘}'. The ‘)' takes the encoder back to copy mode, so it copies ‘ to the output string, and encounters a $( which puts it back into encode mode. Once in encode mode it recognises the $ as the end-of-case, and scans forward until it reaches $\$$, where it stops. We deduce that the set-linetype-0 escape sequence is ‘^[‘. If register 1 had contained a 2, after entering the switch the encoder would have scanned forward to $\$2$ (ignoring all characters as it went), and copied c to the output string.

If you want to support erasing of individual lines (LTYPE ERASE or LTYPE 10) you’ll have to include a $\:\$: case in your switch (as : follows 9 in the ascii character set, and an un-escaped : would end the graphcap entry). You’ll have to escape the : in the 1t list as well. When leaving erase mode, by specifying any other line type, the device will first be set to LTYPE 11 (i.e. ML’ll get a ;) before it’s set to the desired LTYPE; this gives the driver a chance to reset itself. It’s wise to also turn off erase mode when closing the device. An example of an entry supporting erasing lines is a graphon, which includes

:lt=01234\::<CW=^[1^[A^[2\:
:ML=^[^[1(1$0)\'(1$1)a(1$2)c(1$3)d(1$4)b(1$$:

as ‘^[P puts a graphon into erase mode, and ‘^[A takes it out. Note that in erase mode the linetype is set to solid (‘^[‘), so as to erase all types of lines.

There is also a branch instruction, which has syntax

<boolean><offset>;
If the boolean is true (non-zero), then skip (offset - 1) characters in the programme string. The offset may be either positive or negative, and the ‘;’ is at offset 0. For example,

\[(0\#15;)\text{Goodbye}(\#18;)\text{Hello}(\n\]

will print ‘Goodbye\n’ if register 0 contains zero, or ‘Hello\n’ otherwise. As an example of the use of ‘;’, consider using the encoder to decode a string. Remember that ‘;’ meant ‘read a character onto the stack’, and that there was a graphcap capability SC to decode cursor responses. Suppose that we are dealing with a vt240 in REGIS mode, then a cursor read will return a string of the form ‘k[nnn,mmm]’ where ‘k’ is the character you hit, and (nnn,mmm) is the cursor position. We want to put k into register 3, and (x,y) into registers 1 and 2. This is a little messy, as we’ll have to convert the ascii positions into integers. The desired graphcap entry is

\[
\text{SC}=(\#0!1#0!2,13,#0!8,\#48-\!99$0-91\#10*9+1\#118$$8#1=-\#39;\!
0!8,\#48-\!99$0-92\#10*9+12\#118$$8#1=-\#39;62-\!12):\n\]

The first part is simple enough, store 0 in registers 1 and 2, store the first character in register 3, read a character (the [), and store 0 in register 8. Then we come to ,\#48-\!99$0-91\#10*9+1\#118$$8#1=-\#39;. The ,\#48- reads a character and converts it to a digit (48 is the decimal code for ‘0’), then stores it in register 9. The switch then checks if we do have a digit, if so we multiply register 1 by 10 and add the new digit. We then set register 8 to 1 and finish the switch which is here being used as an if statement. The 8#1=-\#39; tests register 8 against 1 (i.e. checks if we found a digit), and if we did it jumps back 39 characters, to read the next character. So we are accumulating the integer nnn in register 1, just as we needed to. The rest of the string deals with decoding the y coordinate.

Sometimes you don’t want to read from the input string, but from the keyboard instead. In this case use ‘str’, e.g. (‘Hello:\ ‘#48-\$0)\text{False}(\$D)\text{True}(\$S)\n: will prompt you with Hello:, then read a character from the keyboard. If you enter a ‘0’ it’ll print False, otherwise it’ll print True. Of course, in reality you’d want to do something more useful (such as erasing the screen).

A.6 Using Cursors with Graphcap

We have just been through a long explanation of how to decode a cursor string, but how did stdgraph know what to read in the first place? After receiving the RC string, the terminal will send back a sequence of bytes, and the format of these bytes must be specified in graphcap. There are two ways to do this, either by specifying a sequence of characters which ‘end’ the response string

\[\text{6 In counting characters for jumps, the ; is at character 0 and combinations such as } \text{\symbol{126}} \text{N count as one character}\]

\[\text{7 If the RC string is given as prompt, then you will be prompted for the key you would have hit, and the (x,y) position the cursor would have been at, if the terminal that you were using could support a cursor.}\]
along with a minimum number of characters to read, or by specifying a pattern that the terminal response is to match. A typical example of the former is a Tektronix whose cursor response may be chosen to be CONTROL-M (this is called the GIN response, and can usually be set in the terminal setup). We know that the terminal will also send 5 other bytes (the key struck and the encoded x,y coordinates so we would specify

:MC=^M:CN=6:

On the other hand, a REGIS terminal sends ‘k[nnn,mnn]’. This can be specified as

:MC=?[#*,#*]:CN=-6:

where the negative value of CN means that we are providing a pattern not just a terminator (as before, the absolute value of CN is the minimum number of bytes in a cursor response). In MC strings, but nowhere else, the characters ?, #, and * are special (although their special meanings may be escaped with a \). ? will match any character, # any digit, and * means ‘match zero or more of the preceding characters’. So a MC string of a#*?ba will match ‘aaa1111bbba’ at the third character. (Incidently, a#*?a would match at the first). Because this special character syntax is different from that used in standard graphcap files for IRAF, the name of this graphcap parameter has been changed from CD to MC.

If your cursor is attached to a mouse, if possible the buttons should be set up to generate ‘e’, ‘p’, and ‘q’ from left to right (if you have that many buttons). If you have only one button, ‘p’ is probably the best choice.

A.7 Using Colours with Graphcap

The number passed to CT are the same as those specified with the CTY INTEGER command, so initially they specify default, white, black, blue, red, green, magenta, yellow, and cyan (white is 1). These are the colours corresponding to turning one, zero, two, or three of the primary colours on. The default colour to use for a device is specified by the DC capability, e.g. :DC="red":.

The CS and CO capabilities are used to support the CTY = expr command. First CS is used to tell the device how many colours to expect, then CO is used for each number, with red, green, and blue as its arguments. In this case CT passes an index into the set of CO values. If you want to get an index, but don’t need CS and CO, you must still provide them; just provide a no-op such as :CS=():.

A.8 How to Modify a Graphcap Entry

You might think that all that you have to do to modify a graphcap entry is to start up your favourite editor, and start typing. You could do that, many people have, but it isn’t recommended
because you'll have to do it again when a new release of SM comes along. It's better to use SM's
graphcap search path (see (undefined) [Graphcap File], page (undefined)) as follows:

Let us assume that you want to modify the xterm entry to print something every-time that is
changes from graphics to alpha mode or vice versa (why? so as to fix a problem with excessive
screen switching). First set up the system `.sm' file to look like:

```
+graphcap /my/private/graphcap
graphcap /usr/local/lib/sm/graphcap
```

which tells SM to first search `/my/private/graphcap' then `~/usr/local/lib/sm/graphcap' (the
graphcap file that we provide) for graphcap entries. Then edit `~/my/private/graphcap' and add
the entry

```
xterm|an xterm with noisy mode flipping:\n:GE=\nE\n:\n^[[?38h:GD=:\nC\n\n:TC=xterm:
```

Note the use of :TC=xterm: which says that SM should skip this file when looking for the definition
of xterm, thus avoiding an infinite loop.

When a new version of SM is released your new definition will continue to work (unless we
change the definition of xterm in which case you'll have some work to do anyway). You can use
this technique to change entries or add your own new ones without modifying the system file; all
of your changes are in `~/my/private/graphcap'.

### A.9 Writing a New Graphcap Entry

So, if you're faced with a new piece of hardware what should you do? First of all, don't panic –
writing entries is quite simple. Second, see if your device is basically the same as one that already
exists in graphcap, for example the entry for `graphon' uses the `selanar' entry, and it in turn uses
`tek4010'. You might be able to get away with using tc to satisfy most of your device’s needs.

Before writing your new entry please read the previous section to learn the recommended strategy
for modifying graphcap files.

Let’s assume that you are faced with a totally new type of device and really do have to start
from scratch. First find out how large your device is, and fill in the xr and yr entries. If you are
going to use hardware character sets you also need ch and cw. Next decide on the string to initialise
the device – does it need to be set into some weird mode – and put it into 0W. Put the string to
reset it into CW. Now, if the initialised device needs to be put into a special graphics mode put it
into GE and its inverse into GD. Next, you need to tell SM how to draw a line and move the plot
pointer. So enter the DS, XY, DE, VS, and VE capabilities. Of course, if one isn’t required, don’t
put it in. If you have some sort of printer you probably want to store all the commands in a file
(OF=), and to plot them (SY=). You should now be ready to make your first test, so plot a box. If
it doesn’t look right, fix it. Or you might like to try printing the cover (load cover cover).
When all is well, you can begin looking into options that might make your graphcap entry more efficient. Look through this appendix to see what is available. Does your device support line types? Add ML and lt. Heavy lines? LW. Coloured lines or a cursor? See (undefined) [Graphcap Colours], page (undefined). Filled polygons? FS, FD, and FE. Dots? MS ME. Hardware characters? TS TE. If your device produces hardcopy you should arrange to start a new page with PG (the PAGE command). When you have finished please send us your new entry.

A.10 Support for Raster Devices

Stdgraph can only handle devices that can plot vectors specified by their endpoints; unfortunately some devices (such as most line printers) can only plot graphs when they have been reduced to rows of ‘on’ and ‘off’ pixels. SM supports such devices through DEVICE raster and a separate programme called rasterise. You specify that a device in a graphcap file is a raster device by using DV: :DV=raster: (The old form :RA: is no longer supported). It communicates with the rasteriser through graphcap, so the whole process is user transparent. A separate rasterising programme was written so as to allow the plot to be produced in the background while you do more productive things, and to allow the rasterising to be done on a remote machine.

DEVICE raster produces a file, whose name is specified as usual by the OF field in graphcap, containing the vectors to be plotted (as groups of four short integers) in device coordinates, where the size of the device is taken from xr and yr. When the device is closed, the command specified by SY are executed, and these will usually be of the form rasterise -r $0 $F outfile\n print_it outfile\n delete outfile where print_it is the proper way of actually getting a plot. Under Unix, the command might well be something like (rasterise -r $0 $F - | lpr -v -r -P$1)& dispensing with the temporary outfile.

What do these rasterise commands do? The command syntax is rasterise [-flags] device infile outfile, where the infile may be specified as ‘-‘ to use standard input (sys$input to VMS), where the outfile may be specified as ‘-‘ to use standard output (sys$output to VMS). Possible flags are r to remove the infile after use, R to rotate the plot through 90 degrees, and v for more verbose operation. Rasterise then reads the data in the infile, and produces a rasterised version, row by row, on the outfile. In order to do this, it looks in graphcap for an entry for device, and uses the xr, yr, OW (and O[XYZ]), and CW fields as usual.8

Let’s first consider a simple, one-line-at-a-time device such as a line printer. Before writing each row to outfile, rasterise encodes the BR (Begin Row) capability, using the current row number as an argument, and encodes ER (End Row) at the end of the line. By default, it assumes that the raster device simply wants bits turned on where a dot is required, but this can be overridden using the BP and EP capabilities. EP (Empty Pixel) specifies the bit pattern for a character to represent

8 In looking for the graphcap file, any environment file or search path specified on the SM command line with a -f or -u flag is ignored.
white space. In the simple case mentioned a moment ago, this would be simply NUL, with no bits on, but sometimes this doesn’t suffice (see examples below). BP (Bit Pattern) is a string, giving the bit patterns required to turn on the various pixels. In the default case, BP could be specified as BP=\001\002\004\010\020\040\100\200, so \001 would turn on the first (rightmost) dot. Because there are eight characters given in the string, raster assumes that it can fit eight pixels into a single character. If you don’t specify a BP this is what will be used. Some devices desire or require that the data be sent as hexadecimal numbers rather than as binary; see the RD=hex graphcap entry.

Some other devices (e.g. Epson printers) choose to print several lines at a time, so a single byte transmitted to the device might print 8 lines, but only the first pixel of each line. Such devices are described to graphcap by being given the MR (Many Rows) capability and a number nb which describes how many bytes deep the printing band is (if omitted nb defaults to 1). In this case, BP is used to describe which bits are turned on vertically rather than horizontally but everything is otherwise the same as for the simple case.

As an example, consider the HP laserjet. You’d specify it as DEVICE laserjet, and its Unix graphcap entry reads:

```
DEVICE laserjet
laserjet|HP laserjet (high resolution):
 :DV=raster:xr#1280:yr#640:CW=^-[*rB:OW=^-[*r1280^-[*rA:BR=^-[*b160W:
 :OF=hp_XXXXXX:\
 :SY=/usr/local/sm/rasterise -r $0 $F - > /dev/hp&:
```

On opening the device, it gets the string `^-[*r1280^-[*rA, setting the resolution and raster mode. Then, at the beginning of each rastered line it gets `^-[*b160W specifying that 160 bytes are coming its way, then finally `^-[*rB to restore it to alpha mode. (It doesn’t need to know which row it is on, so the BR string doesn’t tell it, and the default BP and EP are fine). After the input file is read it is deleted, and the output file is sent to the standard output, whence it is redirected to the proper device, in this case directly rather than through a spooler.

A more complex example is a printronix printer, which encodes 6 pixels in each byte, and requires that bit 7 be turned on. It also needs an escape sequence at the end of each line. The corresponding graphcap entry is

```
DEVICE printronix
printronix|DEC printronix printer:
 :DV=raster:xr#792:yr#792:CW=^-[L:OW=^-[L:BR=^-E\J:\
 :BP=\001\002\004\010\020\040:EP=\100:\
 :OF=pr_XXXXXX:\
 :SY=(/usr/local/sm/rasterise -r $0 $F - | rsh wombat lpr)&:
```

We use EP to turn on the seventh bit everywhere, as required, and specify only 6 values for BP, so only 6 dots will be packed into each character. The BR entry is empty, and ER provides the needed escape sequences at ends of lines. In this case SY sends the plot over a network to machine wombat.

Some devices are not able to simply accept a string of bytes with an occasional escape sequence. For example, a versatec needs to have the bit order changed, or a simple screen plotter might want
to write a * if a bit is set and a space otherwise. If this is the extent of your pathology, you can deal with it via the provided capabilities. (Fortunately adding a * onto a space makes a *, so you can use :EP= :BP=*: for the latter.) If you have a really bad device, it is possible to add new coded device drivers to rasterise. For the convenience of such devices there is a graphcap capability RD which specifies the name of a type of raster device. If rasterise recognises the device it it calls a different set of routines to deal with the rows of data. Otherwise it proceeds as discussed in the previous paragraph. This behaviour is similar to that of the DEVICE command in using stdgraph if it doesn’t recognise a device name.

If you find that you do need to write routines for some device, don’t be too disheartened. Rasterise will still do the book-keeping and rasterising for you, your work will be limited to a couple of output routines. If you need to know more, see the source for rasterise. The only time that I used this capability came about two years after rasterise was written, and was RD=hex which specifies that lines be written as hexadecimal numbers rather than as 8-bit characters (e.g. write the two characters FF instead of the single character ‘\377’). The line length is given as 11.

A.11 Compiling Graphcap

(This section is really for someone maintaining SM.) Rather than have stdgraph read the graphcap every time that it opens a devices, it is possible to compile the capabilities of the more popular devices into the executable. This is done by preparing an include file which initialises the appropriate arrays, using the programme ‘compile.g’ in the main directory. After this file (called cacheg.dat) has been prepared, files depending on it must be recompiled and SM must be relinked. The use of compile.g is pretty much self-explanatory, you give it a list of the devices you want and it produces the cacheg.dat file. Problems arise, however, if you don’t have a valid cacheg.dat file, as then you can’t compile compile.g in the first case. Fortunately, it is possible to bootstrap a cacheg.dat file (by defining BOOTSTRAP to the C-preprocessor), and proceed from there.

When stdgraph attempts to use the compiled capabilities, it checks that the current graphcap file has exactly the same name as the one that cacheg.dat was compiled from, if it isn’t then it reads the graphcap file anyway. This provides a mechanism for those without C compilers to change the graphcap entries of pre-compiled devices. If you have a list of graphcap files, the name of the first is checked against the name in the ‘cacheg.dat’ file.
A.12 Index to Graphcap Capabilities

(Index is empty)

A.13 Calling SM from Programmes

A.13.1 Introduction to Callable SM

The SM callable interface is different from that of Mongo and corresponds directly to the interactive version. Almost all of the commands available in SM can be called from either fortran or C, the exceptions being those concerned with the macro processor, variables, history, and vector manipulations. We assume that if you want to call graphics routines directly, then you are prepared to take responsibility for such things. In C (and probably pascal, modula, or ADA), the calls have the same names as the commands with the prefix sm_, so to set the limits say sm_limits(0.0,1.0,0.0,1.0); On VMS, and with some unix systems (notably HPUX and AIX), if you are writing fortran, you must prepend an ‘f’ to the command - call fsm_limits(0.0,1.0,0.0,1.0). If you forget this ‘f’, your programmes will compile, but they ‘won’t’ work. (They’ll give segmentation violations, most likely. Why? Because you will be calling the C functions directly, not the Fortran interface functions, and the languages have different ways of passing arguments, so e.g. you will pass the address of the variable from your Fortran program to a C function that expects to get the value of the variable. This translation is precisely what the interface functions are set up to do for you).\(^9\) If your fortran compiler cannot find the function names, you might have to read the section on how SM chooses function names (see [Fortran Names], page (undefined)).

So how are you supposed to know what to call the functions? Well, our best suggestion is to ask the person who build SM on your system; the second best suggestion is to look in ‘libplotsub.a’ (or ‘libplotsub.olb’ on VMS systems), and see what the names of the functions are. On VMS, try this:

```
lib/list/names libplotsub/lib
```

and look at the names it lists under module INTERFACE. On a unix system you can use nm (or, if desperate strings). The output is quite long, so I’d filter the output, e.g.:

```
nm libplotsub.a | grep errorbar
```

If you see things in the output like fsm_errorbar, then you know this is one of those machines where you have to prepend the ‘f’ for the fortran interface functions.

\(^9\) Under Unix the loader can often distinguish fortran from C, so you may not need the ‘f’ – call sm_limits(0.0,1.0,0.0,1.0)
If you used an ANSI compiler to link SM (or your guru did) then you should provide prototypes for the SM functions that you call if you use the C interface (Fortran knows nothing of such things). This can be done by including the file `sm_declare.h'.

In what follows, we will assume that you are not writing fortran under VMS, so we will omit the leading es.

To use SM functions, you must link with appropriate libraries. You will always need to link with the three SM libraries, `libplotsub', `libdevices', and `libutils' in that order. Specifically, under Unix, you'll need to include the files `libplotsub.a', `libdevices.a', and `libutils.a' when you link (it's probably easier to use `-lplotsub -ldevices -lutils', along with a `-Ldir' if needed). and under VMS you'll need `libplotsub.olb/lib', `libdevices.olb/lib', and `libutils.olb/lib'. I can't tell you where they'll be on your system. In addition, you may need to link (after `utils') any libraries used by the devices that have been compiled into your version of SM. For example, if you use the X-windows driver, you'll need to link with the X-library (`-1x'). Consult a local guru in case of any trouble - the person who installed SM has had to work this out already.

A.13.2 Example of Calling SM Functions

A list of functions giving the calling sequence for all the available functions follows, but first an example. Note especially the use of `graphics' and `alpha' to set the terminal to graphics mode, and return to a normal terminal afterwards. We would recommend always calling these, if they do nothing (e.g. on a laser printer) they'll do no harm. A related function is `gflush()' which will update graphics on the screen, for instance with stdgraph where output is usually buffered.

Some devices (such as GL on an SGI, or X-windows on machines without backing store such as RS/6000's) need some help from you to redraw the screen. You do this by calling `redraw' whenever you are waiting for input, passing it '0' (the file descriptor of standard input, for those of you familiar with C). When input is ready, `redraw' will return and your application can proceed. It should do no harm on systems where it does no good.

If you don't want to be bothered with calling `sm_alpha', `sm_graphics', `sm_gflush', and `sm_redraw', see (undefined) [Why call `sm'alpha?], page (undefined).

There are examples of programmes (in both C and fortran) calling SM in the directory `sm/callable'; you might want to look at them before starting your own project.

```c
integer NXY
parameter (NXY=20)
integer sm_device
integer i
real x(NXY),y(NXY)

do 1 i=1,NXY
   x(i) = i
   y(i) = i*i
```

continue

if(sm_device('hirez') .lt. 0) then
    print *, 'Can''t open hirez'
    stop
endif

call sm_graphics
call sm_defvar("TeX_strings","1")
call sm_limits(-1.,22.,0.,500.)
call sm CType('red')
call sm_box(1,2,0,0)
call sm_ptype(40.,1)
call sm_points(x,y,NXY)
call sm_xlabel('X axis')
call sm_ylabel('Not x axis')
call sm_alpha
print *, 'hit any key to exit'
call sm_redraw(0)
read(5,*) i
end

Remember, if you were running VMS, HPUX, or AIX then all those calls would start 'f' - call
fsm_graphics and so forth. Note that sm_box takes all of its four possible arguments, and that
commands such as sm_points add an argument to specify the number of points to plot. You must,
of course, ensure that you use the correct type of variables, passing integers or reals as required
(and as listed below). If you are using C, you must carefully distinguish between passing by value,
and passing by address (which we only use when an array is expected, and for returning a cursor
position).

A.13.3 Function Definitions: 1-D

The functions are as follows. For fuller definitions of the arguments look at the main description
of the command. The only ones that are different are sm_curs, sm_defvar, and sm_plotsym
because they don’t quite correspond to any interactive commands. A common source of trouble is
not noticing that the sm_ptype call is the vector form of the command, so to set a ptype of ‘4 1’
you must say sm_ptype(41.0,1).

The arguments are declared in fortran in this list. real x(n) means that x is an array of size
n. ‘Real’ means single precision. (So in C, character → char *; integer → int; real → float;
real() → float *. We deal with converting the calling conventions from one language to another,
but note comments at the bottom of this table.)

sm_alpha  Set terminal back to a normal state
sm_angle(a)
  Set angle to a (real a)
sm_axis(a1,a2,as,ab,ax,ay,al,il,ic)
    Draw an axis. (real a1,a2,as,ab; integer ax,ay,al,il,ic)

sm_box(x1,y1,x2,y2)
    Draw a box - note 4 args. (integer x1,y2,x2,y2)

sm_connect(x,y,n)
    Connect a line. (real x(n),y(n); integer n)

sm_conn(x,y,n)
    Equivalent to sm_connect

sm_cctype(c)
    Set colour to c (character c)

sm_cctype_i(i)
    Set colour to i (integer i)

sm_curs(x,y,k)
    Return position of cursor (real x,y; integer k)

sm_defvar(str1,str2)
    Select variable str1 to str2 (character str1, str2)

sm_device(str)
    Select device str (character str); return integer

sm_dot
    Draw a dot

sm_draw(x,y)
    Draw to (x,y) in user coords (real x,y)

sm_erase
    Erase screen

sm_errorbar(x,y,e,k,n)
    Draw error bars (real x(n),y(n),e(n); integer k,n)

sm_expand(e)
    Set expand to e (real e)

sm_format(xf,yf)
    Set format strings to xf and yf (character xf,yf)

sm_get_variable(name) (character name)
    Return the value of the variable name, if it's a special variable

sm_gflush
    Flush graphics output

sm_graphics
    Set terminal into plotting mode

sm_grelocate(x,y)
    Relocate in screen coordinates (integer x,y)
sm_grid(i)
    Draw a grid (integer i)

sm_hardcopy
    Close current device, if appropriate make hardcopy

sm_histogram(x,y,n)
    Draw a histogram (real x(n),y(n); integer n)

sm_identification(str)
    Identification string (character str)

sm_label(str)
    Draw a string (character str)

sm_limits(x1,x2,y1,y2)
    Set limits (real x1,x2,y1,y2)

sm_location(x1,x2,y1,y2)
    Set location (integer x1,x2,y1,y2)

sm_ltype(lt)
    Set ltype (integer lt)

sm_lweight(lw)
    Set lweight (real lw)

sm_notation(xl,xh,yl,yh)
    Set axis format defaults (real xl,xh,yl,yh)

sm_page()
    Equivalent to PAGE interactively

sm_plotsym(x,y,n,sym,ns)
    Draw user points (real x(n),y(n); integer n,sym(3*ns),ns)

sm_points(x,y,n)
    Draw points (real x(n),y(n); integer n)

sm_ptype(pp,n)
    Set point type - vector form (real pp(n); integer n)

sm_putlabel(i,str)
    Position a label (integer i; character str)

sm_redraw(i)
    Wait for input on file descriptor i (integer i).

sm_relocate(x,y)
    Relocate in user coords (real x,y)

sm_set_ctype(cols,n)
    Set SM’s permitted colours to cols (real cols; integer n)

sm_shade(delta,x,y,n,type)
    Shade a region (integer delta; real x(n),y(n); integer n,type)
\texttt{sm_ticksize(xs,xb,ys,yb)}
Set ticksize (real xs,xb,ys,yb)

\texttt{sm_window(nx,ny,x,y,x2,y2)}
Select a window (integer nx,ny,x,y)

\texttt{sm_toscreen(ux,uy,sx,sy)}
Convert to screen coordinates (real ux,uy, integer sx,sy)

\texttt{sm_xlabel(str)}
Draw x-axis label (character str)

\texttt{sm_ylabel(str)}
Draw y-axis label (character str)

\texttt{sm_device} returns 0 if it opens the requested device, or -1 if it fails. You must declare \texttt{sm_device} as returning integer, of course. \texttt{sm_curs} returns after you hit any key, returning the coordinates of the point, and the key struck as an integer (e.g. ‘a’ as 97 in ascii). In C, all three arguments are pointers, two to float and one to int. \texttt{sm_defvar} defines a variable, it is identical to the interactive command \texttt{DEFINE name value}. It is only used to certain define variables that are significant to SM, currently \texttt{file_type}, \texttt{graphcap}, \texttt{TeX_strings}, \texttt{x_gutter}, and \texttt{y_gutter}. Fortran users might or might not need to double `\textbackslash` in \TeX labels, depending on the foibles of your compilers (you are more likely to need the doubled `\textbackslash` under unix).

\texttt{sm_plotsym} is like first using the \texttt{PTYPE \{ ... \} command to define \texttt{sym}, and then \texttt{POINTS} to plot \texttt{x} against \texttt{y}. The \texttt{sym} array consists of triples of integers, (move \texttt{x y}) where move is 1 to move the plot pointer, 0 otherwise. This is not quite the same as the interactive command, but doesn’t involve any characters. The \texttt{move} integer may not be omitted. The ‘file descriptor’ that \texttt{sm_redraw} demands will almost always be 0 (standard input) on unix boxes; if it is needed by VMS or other operating systems I will add a note here when I write the device driver. \texttt{sm_shade} shades the inside of the curve specified by \texttt{x} and \texttt{y} if type is 1, or the area below a histogram specified by \texttt{x} and \texttt{y} if type is 2. The line spacing in screen coordinates is delta. You can use \texttt{sm_toscreen} to convert from user to screen coordinates (which run from 0 to 32767, and are used by \texttt{sm_grelocate}). The second pair of arguments should be pointers to int if called from C.

\texttt{sm_window} takes an extra two arguments over the interactive version; they are the values that you’d specify using the \#:\# form of window specification; for example, \texttt{WINDOW 4 5 1 2:3} corresponds to the call \texttt{sm_window(4,5,1,2,1,3)}.

The colour functions are \texttt{sm ctype} and \texttt{sm ctype_i}, equivalent to \texttt{CTYPE name} and \texttt{CTYPE integer} respectively, and \texttt{sm_set ctype}, equivalent to the numerical form of \texttt{CTYPE = expr}.

You can get at most of SM’s ‘special’ variables (e.g. \texttt{expand}) directly by looking at C globals (these may look like common blocks to fortran, it depends on your compiler); look in the file ‘src/plotsub/set.c’ for details. Alternatively (and less involved in SM’s insides, if a bit slower), you can use \texttt{sm get variable}, which will return values as floating point numbers.
The functions to manipulate 2-dimensional data are described in the next section.

A.13.4 Function Definitions: 2-D

The use of the 2-D functions may require a little more explanation. If you want to use SM to read your data, producing contour plots is very similar to doing so interactively, with the difference that instead of defining the variable file_type, you must call the function sm_filetype with the desired value as the argument before reading the data. This is equivalent to calling sm_defvar to define the variable file_type, and is only supported for backwards compatibility. As an alternative, you can fill your own data array, and pass it to SM to be contoured with sm_defimage.

Please note: the image data that you provide to SM should be 4-byte floats even if you are built SM to use 8-byte (double) floating point numbers.

The function calls follow (again in fortran), followed by some explanation.

\texttt{sm\_contour}

Contour current 2-D image

\texttt{sm\_defimage(arr,x1,x2,y1,y2,nx,ny)}

Define an image (real arr(nx,ny),x1,x2,y1,y2; integer nx,ny)

\texttt{sm\_delimage}

delete current 2-D image

\texttt{sm\_filetype(type)}

Set 2-D filetype (character type)

\texttt{sm\_levels(l,n)}

Set levels for contour (real l(n); integer n)

\texttt{sm\_minmax(x,y)}

Get minimum and maximum of image (real x,y)

\texttt{sm\_readimage(file,x1,x2,y1,y2)}

Read a 2-D image (character file; real x1,x2,y1,y2)

The translation to other languages is not quite as simple as above. In C, \texttt{sm\_minmax} expects to be passed pointers to floats, and the first argument to \texttt{sm\_defimage} is not a 2-D array, but an array of pointers to the rows of the image. x1, x2, y1, y2 specify the limits as in the interactive IMAGE command; if they are set to be 0.0 then the dimensions of the array will be used. As an example, again in non-VMS fortran:

\begin{verbatim}
integer NXY
parameter (NXY=20)
integer sm_device
integer i,j
real z(NXY,NXY),lev(NXY)
\end{verbatim}
do 2 i=1,NXY
  do 1 i=1,NXY
    x(i,j) = (i-NXY/2)**2 + (j-1)**2
  1 continue
2 continue

if(sm_device('postscript latypus') .ne. 0) then
  print *, 'Can`t open printer'
  stop
endif

call sm_graphics

call sm_limits(-1.,21.,-1.,21.)
call sm_box(1,2,0,0)
call sm_defimage(z,0.,20.,0.,20.,NXY,NXY)
call sm_minmax(amin,amax)
do i=1,NXY
  lev(i)=amin + (i - 1.)/(NXY - 1)*(amax - amin)
3 continue

call sm_levels(lev,NXY)
call sm_contour
call sm_hardcopy
call sm_alpha
end

A.13.5 Calling the SM interactive Parser from Programmes

It is also possible to call the SM parser directly from your own programmes. This is usually
done by people who have large data arrays that they want to plot, so we have also provided a call
to define your arrays as SM vectors. To use this, your SM guru must build an extra library, (called
`libparser.a` on unix systems). This is done with the command

    make Parser

in the top level SM source directory. If this has been done, you can link the parser into your
code by including the flag `-lparser` before the other SM libraries (but after any -L flags). The
programmes `interp` and `finterp` in the `callable` directory provide examples of calling SM’s
parser; `finterp.f` looks like:

    real a(10)
    integer i

    do 1 i=1,10
      a(i) = i
1    continue
call sm_array_to_vector(a,10,'xyz')
print *, 'Calling SM parser...'
call sm_parser('-q')
print *, 'Exited parser'
end

Here the array \(a\) (with 10 elements) is to be called \(xyz\) in SM, and SM is to be invoked with the command line options \(-q\). You can of course define as many vectors as you feel like, but using DELETE to delete them from the parser is a serious error (i.e. don’t!).

\[
\text{sm_array_to_vector(arr,n,name)}
\]

Define an SM vector called \(name\) to have the values of the array \(arr\). (real \(arr(n)\); int \(n\); character \(name\)).

\[
\text{sm_parser(args)}
\]

Start up the SM command parser as if you had started SM interactively with command line arguments \(args\), but with some vectors predefined (those that you defined using \text{array_to_vector}\) (character \(args\)).

A.13.6 Why do I have to call \text{sm_alpha}, \text{sm_graphics}, \text{sm_gflush}, and \text{sm_redraw}? 

The question sometimes comes up, ‘Why do I have to bother with these calls \text{sm_alpha}, \text{sm_graphics}, \text{sm_gflush}, and \text{sm_redraw}? After all, other graphics libraries don’t require them.’

The answer is that it all depends on how sophisticated and device dependent you want to be.

If you are using something like an xterm to plot to, then yes, you do need to explicitly switch between graphics and alpha screens – or else you’ll get gibberish on the text screen (something like ‘\(?_"s#M"s>\!"s#M#b#M!s#F!s#F0"s$X"\) and no graphics on the graphics screen, or else your graphs and your input commands (and some gibberish to handle the screen editor) mixed together on the graphics screen. Of course the SM routines could have done the switches for you, but if the mode were changed everytime that it might need switching, you’d get an immense amount of mode switching. Why would that matter? Try running the code on a terminal like a vt240 that physically has only one screen.

If you didn’t care about devices like xterm and were determined to only use devices like x11 or sgi or postscript you wouldn’t have to worry about any of this.

Next to gflush. For efficiency, SM doesn’t guarantee that every write request is actually written to the screen when received, so at the end of a function call there could be lines or points that haven’t yet reached the screen. gflush deals with this by flushing the graphics buffers, thus ensuring that all pending writes to the screen are completed. If you don’t care about possible missing points, don’t worry about it.
Finally **redraw**. On a traditional terminal such as an I^2^S or a tektronics 4010, there was no need to worry about other windows appearing on top of your beautiful graphics window and erasing what was there; for some devices such as `xterm` there is no problem as the terminal emulator is always looking at the screen, like a faithful dog, waiting for you to type something or for one of its screens to get corrupted. In the old days of sunview, Sun had hacked the lowest level system calls (read etc.) to allow an application programme to call the equivalent of **redraw** automatically (well, under a reasonably common set of conditions). But if you are running on something like an X11 display or a GL display on an SGI, there is no-one looking out for events that erase your window, and you have to do it yourself. If you don’t care about refreshing the screen when raised to the top of the window stack, there’s no need to worry about **redraw**.

So all these complications with **alpha**, **redraw**, and friends are due to SM being designed to handle all the possible nasty cases. If you use SM interactively, it is all done for you, but if you want to call SM functions you have to decide how much responsibility you want to take.

Of course, you can write a trivial wrapper about each SM primitive that calls `sm_graphics` before calling (e.g.) `sm_points`, then `sm_gflush` and `sm_alpha` just before returning. In a similar way, you could write a general i/o function that calls `sm_gflush` then `sm_alpha`, then prompts you, then calls `sm_redraw`, then reads the reply, then calls `sm_graphics`. But I don’t think that the SM primitives should do it for you.

### A.13.7 How to Choose the Name for Fortran Subroutines

As discussed above, the names used for SM callable functions from fortran are, in general, different from those used in (almost?) all other languages, as fortran’s calling conventions are different, so we have to provide interface code (in the file `sm/src/plotsub/interface.c`). The SM function `sm_func` may be called as `AAAsm_funcBBB` where AAA and BBB are the values of the C-preprocessor macros `FORTRAN_PREPEND` and `FORTRAN_APPEND` respectively; their default values are nothing and `_`. If you want to change this, edit `sm/src/options.h` and define the values that you desire. Note: with C compilers that don’t adhere to the C89 ansi standard, you are restricted to the values `f` and `_` for `PRE-` and `APPEND`.

After changing `options.h` (or `options.skl` if you want your changes to survive the running of `set_opts`), rebuild SM and you should be in business.

### A.14 The SM Grammar

Previous editions of this manual included a printed copy of the SM grammar, prepared directly from the source code using the `get_grammar` utility. This was helpful in understanding otherwise bizarre objections to your favoured command, as it specified exactly what SM would accept, but used a lot of paper. We have therefore omitted it from this edition, but you are welcome to make yourself a copy.
A.15 Two-Dimensional Graphics

There is limited support for 2-dimensional graphics in SM, and we do not expect to make many extensions in this area. Currently it is possible to read an unformatted image, to draw contours, to generate a Floyd-Steinberg dithered image, to extract values from the image into vectors, and to obtain image values with a cursor. Previous editions of this manual (prior to version 2.3) have traditionally said: ‘We expect to support half-tone imaging in the nearish future’; as of this release there is a macro (called greyscale and written by Gabor Toth here at Princeton) that draws reasonably efficient grey scale images on any supported output device.

The problem of specifying data formats for images is difficult, and we have adopted an approach of using a ‘filecap’ file to describe the unformatted files. This allows the user to write the file using C or Fortran (or, presumably, lisp) and then use SM to read the data. The name of the entry in the filecap file is given by the variable file_type, which may be given in your ‘.sm’ file if you use the standard startup macro. The format of data on disk is first the x- and y- dimensions of the image, then the data in row-ascending order. The exact statements used to write the data may depend on the chosen value of file_type (or vice-versa). A description of the filecap fields comes at the end of this appendix; most users should never have to change this file.

It is also possible to read data from a formatted file and create an image inside SM, for example if x and y are integers in the range 0-9:

```
IMAGE (10,10) # declare a 10*10 array
READ { x 1 y 2 vals 3 } # read some data
SET IMAGE(x,y) = vals # and put it into the image
```

The command used to read an image is IMAGE, and you may optionally specify the x and y range covered by the data (e.g. IMAGE datafile xmin xmax ymin ymax; this also works with declarations like the one in the previous paragraph). Only the region of the image lying within the current limits is plotted when contouring - just like any other graphics operation in SM. Images may be deleted with the DELETE IMAGE command. To extract values from an image, use the special expression \( \text{IMAGE(vec}_x,\text{vec}_y) \) which has the value of the image at the points (vec\_x,vec\_y).

You can extract variables from the image’s header using the command DEFINE name IMAGE. See the discussion of filecap if you need to know what variables can be retrieved this way.

If you want to use non-interactive SM (i.e. write your own command interpreter), there is a call (defimage) to define your data array to the contouring package, but this is of course not available interactively.

A.15.1 Filecap

Filecap is similar in graphcap or the Unix termcap, and in fact the ‘filecap’ entries may be physically in the same file as graphcap (i.e. added as if they were graphcap entries; of course an
attempt to say device fits will lead to confusion...). Filecap can be specified as a list of files to be searched in order. The fields in filecap are used to specify the data type of the file, the record format of the file (record-length, inter-record gaps, etc.) and the header used (length of header, offset of desired items). Note that these are ‘unformatted’ files, as written by C write() or fortran write(num) statements.

The current filecap is as follows:

```
# Filecap describes unformatted file formats to SM. The syntax is
# identical to termcap or graphcap files.
#
# c|C|C files:
   :HS#8:nx#0:ny#4:
ch|CH|C files with headers:
   :HS#24:nx#0:ny#4:x0#8:x1#12:y0#16:y1#20:
fits|cfits|FITS|CFITS|C FITS files:
   :DA=fits:RL=2880:
no_header|Files with no header, will prompt for nx, ny:
   :HS#0:
unix|UNIX|Fortran unformatted files under Unix on a Vax:
   :HS#1:nx#0:ny#4:RS#4:RL#1:RE#4:
unix_int|UNIX_INT|Like unix, but integer*4:
   :DA=int:tc=unix:
unix_short|UNIX_SHORT|Like unix, but integer*2:
   :DA=short:tc=unix:
vms_var|VMS_VAR|Fortran unformatted under VMS, recordtype=variable:
   :HS#8:nx#0:ny#4:
vms_fixed|VMS_FIXED|Fortran unformatted under VMS, recordtype=fixed:
   :HS#1:RS#0:RL#1:REnx#0:ny#4:
   # This seems to be correct, based on one example
vms_direct|VMS_DIRECT|Fortran unformatted, direct access, under vms:
   :HS#8:RS#0:RE#0:nx#0:ny#4:
```

Comment lines start with a #, continuation lines start with white space (a tab or a space) and \ may be used to continue an entry on to the next line. The first few fields in an entry are separated by 1, and are alternative names for the same entry. For example, fortran unformatted files under Unix may be referred to as unix or UNIX. Fields are separated by colons, and are of the form :CC#nnn: for numbers, and :SS=str: for strings. Omitted fields may be specified as :CC@nnn:, or simply omitted. Filecap capabilities currently used are:

DA (Data type)
   Type of data in file (string)

FS (File Start)
   Unwanted bytes at start of file

HS (Header Size)
   Size of header
Appendix A: Appendices

RE (Record End)
Unwanted bytes at end of record

NS (No Swap)
Don’t swap bytes for FITS files

RL (Record Length)
Number of useful bytes per record

RS (Record Start)
Unwanted bytes at start of record

SW (Swap) Byte swap 2 by integer data, and byte-and-word swap 4 by integers.

nx (Number X)
Offset in file of X size of data

ny (Number Y)
Offset in file of Y size of data

x0 (X 0) Coordinate at start of X axis

x1 (X 1) Coordinate at end of X axis

y0 (Y 0) Coordinate at start of Y axis

y1 (Y 1) Coordinate at end of Y axis

In addition, HH is supported as an archaic form of HS.

In terms of these quantities a file will look like this:

| FS | HS | RS | RL | RE | RS | RL | RE | ...

The distinction between single and double lines is purely visual. As mentioned below, HS can be negative and is then taken as the record length of the header $RL_H$, in which case the file will be like:

| FS | RS | $RL_H$ | RE | RS | RL | RE | RS | ...

Note that the first real data record begins with an RS – this means that if you are writing fortran you must write the header in a different write statement than the one that you use to write the data (i.e. `write(fd) nx,ny,arr` will not work).

Most parameters are optional, and will default to 0. If RE or RS is specified, you must give RL as well. If you specify it as negative, then we’ll look for it from the operating system. You must provide a value for HS (or HH if you’re old fashioned), if it is negative we’ll assume that even the header has a record structure, with RS and RE just like any other record. Its record length will be taken to be RL, if RL is positive, otherwise we’ll find it from the operating system. If HS and RL are both negative there is no reason why the record length of the header should be the same as that of the data.
If neither \( nx \) nor \( ny \) are present in the graphcap entry you will be prompted\(^{10}\) for the \( x \) and \( y \) dimensions of the file, otherwise they must both be present. If they are negative they are taken to be the negation of the true dimension (so a filecap entry \( :ny#-6: \) specifies that the \( y \)-dimension of the data is 6), but usually they are taken as the offsets of the values of the \( x \) and \( y \) dimensions in the file, relative to the start of the header (if you set \( HS \) to be zero you can specify \( nx \) and \( ny \) on the command line, but they must be on a separate line, either a real separate line, or following a \( \backslash n \)). Note that \( HS \) excludes \( FS \), so \( HS \) will usually be \( 2 \times \text{sizeof(int)} \) irrespective of the value of \( FS \), and \( nx \) will usually be 0. If \( HS \) is negative, then the \( nx \) and \( ny \) offsets also ignore \( RS \), i.e. \( nx \) is still usually 0.

As an alternative to specifying the actual file sizes as negative integer values of \( nx \) or \( ny \) (e.g. \( :nx#-10: \)) you can simply specify them as positive string values: \( :nx=10: \). Note how this differs from \( :nx#6: \).

Possibilities for \( DA \) are \texttt{char}, \texttt{float} (default), \texttt{int}, \texttt{long}, and \texttt{short}, all as in C, and also \texttt{fits} for FITS format data. (If you don’t know what FITS format is, don’t worry about it. It’s a style of header and record structure used for data transport in astronomy\(^{11}\). If you do know about FITS, then we assume that each record is 2880 by long, although possibly with \( RS \) and \( RE \) non-zero. The header is processed for the size of the file and the value of \( BITPIX \). If the file is not SIMPLE, it is taken to be 4 by floating point data. \( CRPIX \), \( CRVAL \), and \( CDELT \) are interpreted correctly, as are \( BZERO \) and \( BSCALE \). \( X0 \), \( x1 \), \( y0 \), and \( y1 \) are specified as the keywords \( X0 \), \( X1 \), \( Y0 \), and \( Y1 \) respectively, and take preference over \( CRPIX \) etc. FITS files on a machine with vax byte order are supposed to be byte swapped, but you can override this by specifying the \texttt{NS} capability which stops SM from doing any byte swapping. If you specify \texttt{SW} it takes preference over any other instructions about byte swapping and forces byte-swapping for 2 byte (short) data, and byte-and-word swapping for 4 byte (int) data. If \( x0 \) and \( x1 \), or \( y0 \) and \( y1 \) are omitted, the range of values on the appropriate axis is taken to be 0 to \( nx-1 \) (or \( ny-1 \)). You can override these values with the \texttt{IMAGE} command. The values of \( X0 \) (and so on) can be obtained directly using \texttt{DEFINE X0 IMAGE}; Other values can be specified in ‘filecap’, for example a filecap entry \( :aa#24: \) specifies that \texttt{DEFINE aa IMAGE} should recover the (floating-point) number stored at byte offset 24. Because of the way that filecap files work, you are restricted to two-character names. If you are using FITS files, all the keywords from the header are available, but you should remember that SM is case sensitive.

For example, suppose I wrote a file using the Unix \texttt{f77} compiler, with some code that looked like:

```plaintext
integer *4 nx,ny,arr(10,20)
```

\(^{10}\) in fact they will be read from a macro or the command line without prompting if they are available; try \texttt{define file_type no_header image file \n 10 20}

\(^{11}\) The usual reference is Wells, D.C., et al. Astron. Astroph. Suppl, \textbf{44} 363 (1981), although FITS is in fact becoming a national standard in the US
c

    nx = 10
    ny = 20
    write(8) nx,ny
    write(8) arr

(Omitting opening unit 8 as an unformatted file, and filling the array with data). Then I could read it in SM by defining file_type to be unix_int. The filecap entry indicates that the length of the header is to be obtained from unix (in fact from the file, it’ll be the record length of the header), as is the record length. Both the start-of-record (RS) and end-of-record (RE) gaps are 4 by long (they in fact contain the record length, but you needn’t know that). The number of x-records is at zero offset in the file, and y-records is at offset 4. In other words, allowing for FS being 0 and RS being 4, nx occupies bytes 4-7 in the file, and ny 8-11. The data is taken to be 4-byte integers (integer*4 to fortran). In fact, the first record consists of only the values of nx and ny, so the record length of the first record is 8 by, and part of an equivalent filecap entry would be

:FS#4:HS#12:

where I have interpreted RS as FS, and added the RE onto the end of the header length HS. If I had written the data out line-by-line in a do loop, the file type would still be unix_int, but the record length actually used by SM in reading the file would be different (see (undefined) [Image], page (undefined)).

As another example, I use an image processing system called Wolf that used to use files with the arcane structure of 200 bytes of header, then the x- and y-size of the file, given as ints, then more header up to a total offset of 1024 bytes from the start of the file, then the data written as short integers. I could write a header with code that looked somewhat like (omitting all error checking):

    int fd,i;
    int xs = 20,ys = 10;
    short arr[10][20];
    ...
    lseek(fd,200L,0);
    write(fd,(char *)&xs,sizeof(int);
    write(fd,(char *)&ys,sizeof(int);
    lseek(fd,1024L,0);
    for(i = 0;i < ys;i++) write(fd,(char *)arr[i],xs*sizeof(short));

The corresponding filecap entry is

    wolf|Wolf-IfA files:
    :HS#1024:nx#200:ny#204:DA=short:

which is pretty simple really.
A.16 Termcap – A Terminal Database

Termcap is a Unix idea, that makes it possible to write software that runs on a wide range of different terminals. The implementation that SM uses contains no Unix source code. The idea is similar to graphcap or filecap – each property of the terminal is given as a field in a file. For example, the string to clear to end of line is called ce, and for ansi terminals is given as ce=CONTROL-[[K. The format for termcap files is described under ‘graphcap’, which is identical. Our termcap is identical to the Unix one, so for details see section 5 of the Unix manual. The file to use as a termcap file is specified as termcap in your ‘.sm’ file, or as the environment variable TERMCAPE (logical variable to VMS). If SM can’t open TERMCAPE as a file, it is taken to be the value of the entry for your terminal. If it doesn’t begin with a colon, it is treated like a termcap file, and searched for the desired terminal. If it does begin with a colon, it is simply taken to be the termcap entry to use. A TERMCAPE variable takes precedence over an entry in your ‘.sm’ file. As for graphcap, a list of termcap files can be specified, to be searched in order.

A full termcap entry can be pretty long, but fortunately SM only uses a small subset. (The rest are needed by full scale screen editors, but we haven’t written one.) In particular we use:

c (Clear End)
  Delete to end of line
ch (Cursor Horizontal)
  Move cursor within line
cm (Cursor Movement)
  Move cursor around screen
cn (ColumnS)
  Number of columns on screen
dc (Delete Character)
  Delete character under cursor
is (InitialiSe)
  Initialise terminal
ks (Keypad Start)
  Initialise Keypad
ks (Keypad End)
  Undo Keypad Initialisation
kd (Kursor Down)
  Move cursor down one character
kl (Kursor Left)
  Move cursor left one character
kr (Kursor Right)
  Move cursor right one character
ku (Kursor Up)
   Move cursor up one character

k1 (Key 1)
   Key sequence emitted by PF1 key (also k2, k3, and k4)

li (Lines)
   Number of lines on screen

pc (Pad Character)
   Pad character, if not NIL

All of these are strings except co and li which expect numbers, and pc which expects a single character. The editor uses all of these except co, although the k ones are only provided as a convenience to you, mapping the arrow keys. In fact, these arrow keys may supersede desired bindings such as control-K to delete to end of line (e.g. on a televideo 912). If this happens, use the EDIT or READ EDIT commands to fix things up.

The cursor addressing strings ch and cm use a variant of the C printf %. Consider the string as a function, with a stack on which are pushed first the desired column, and then the desired line (so the line is on top). The possible % formats operate on the stack, and pop it after output.

d   As in printf, zero origin
2   Like %2d
3   Like %3d
.   Like %c
+x  Add x to value, then ‘%.’
>xy  If value > x add y (no output)
r   Interchange line and column (no output)
i   Increment line and column by 1 (no output)
%   Output a single %

We do not support %n, %B, or %D out of pure laziness. A couple of examples might help. To go to (5,60) a vt100 expects to receive the string control-[[5;60h, so the termcap entry reads :cm=\E[%i%d;%dH: . We need the %i to go to one-indexed coordinates, and the escape is written \E. The ’s delimit the termcap entry. A Televideo 912 expects to be given first control-[=, then the coordinates as characters, where ‘ ’ is 0, ‘!’ is 1, and so forth through the ascii character set. To convert a given number to this form we add ‘ ’, so the termcap entry is :cm=\E=%+ %+ :.

If an entry begins with a number, it gives the number of milliseconds of padding that the terminal requires (it is optionally followed by an *, which we can and do ignore). If the terminal requires a pad character that is not simply ascii NIL it should be given as pc, so to use ‘a’ as a pad character
specify \texttt{:pc#97:}. The baudrate is taken to be 9600, unless you specify it as the \texttt{ttybaud} variable in your \texttt{.sm} file. We have never yet seen SM have any trouble with padding, so we wouldn't worry about any of this if we were you.

You might wonder why we need both \texttt{ch} and \texttt{cm}. The simple answer is that we don't, but that we do want one of them. Because \texttt{cm} moves the cursor to a specific line, its use requires that SM remember which line you are on which can be tough what with switching to and from graphics mode. We therefore assume that you are on the last line of the terminal, as set by \texttt{li} or explicitly by the \texttt{TERMTYPE} command. If you provided \texttt{ch} this problem wouldn't arise but many terminals don't support such a capability and we have to code around this deficiency. To summarise: use \texttt{ch} if you can, failing that use \texttt{cm}.

There is a problem with using the last line of the screen as the SM command line, and this is that some terminals use the same screen for graphics as for text, and your graph will merrily scroll away as you type. The graphcap \texttt{GD} (Graphics Disable) command can be set to take you to the top of the screen, but \texttt{cm} won't keep you there. Your only chance is to disable cursor motion, either by setting \texttt{ch} to 'disabled', or by specifying a negative screen size to \texttt{TERMTYPE} which has the same effect. You can still use the editor, but it'll be slower. If you still have trouble, try \texttt{TERMTYPE dumb}, which really is a bit brain damaged, or \texttt{TERMTYPE none} which disables the editor entirely.

\section*{A.17 New Devices and New Machines}

\subsection*{A.17.1 Adding New Devices}

As we have discussed extensively (see (undefined) [Graphcap], page (undefined)), most plotting devices can be accommodated within the framework of stdgraph/graphcap without writing a line of C; raster devices can use the raster device driver. Sometimes, however, this is not possible and you must write a real driver. An example would be making SM run native under X11; running under a terminal emulator can be done with graphcap.

If you do make any changes, write any new drivers, or modify graphcap (except trivially) please send us copies of your modifications.

Let us assume that you really do need a new driver, how do you go about it? SM communicates with devices solely through a graphcap entry, some external variables (defined in \texttt{sm.h}) and a structure called \texttt{DEVICES} which is defined in \texttt{devices.h} and declared in \texttt{plotsub/devices.c}.

When you issue a \texttt{DEVICE devname args} command, the stdgraph driver is called with the string \texttt{devname args}, and it opens the graphcap entry for \texttt{devname}. If it finds an entry of the form \texttt{:DV=driver:} it tries to find a hardcoded device driver called "\texttt{driver}" (you'll see in a moment where the names come from). If it can find such a driver it calls its setup function (to be defined in
a moment) with *args* as an argument. Your device driver is now in charge, and no more stdgraph routines are called until your device is closed; after you return from your close function stdgraph’s close function is called to close the graphcap descriptor. What do you have to remember from this paragraph? That you need a graphcap entry, if only a trivial one along the lines of

```
my_device|all_mine:DV=my_driver:
```

which associates the driver *my_driver* with the device referred to as either *my_device* or *all_mine*. Because stdgraph’s stg_open and stg_close functions are called around your device code the standard graphcap support for OW, IF, DC, OF, SY, and CW is automatically provided if you want it; see the imagen driver and graphcap entries for an example. You might also want to remember that you can directly access any graphcap entry for your device from within your driver, using the functions ttygets, ttygetr, ttygeti, and ttygetb.

The current definition of *DEVICES* looks like this:

```c
typedef struct {
    char d_name[40]; /* name of device */
    int (*dev_setup)(); /* initialisation */
    void (*dev_enable)(), /* enable graphics */
    void (*dev_line)(), /* draw a line from x1, y1 to x2, y2 */
    void (*dev_reloc)(), /* relocate current position */
    void (*dev_draw)(), /* draw a line from current pos to x,y */
    int (*dev_char)(), /* hardware characters */
    int (*dev_ltype)(), /* hardware line type */
    int (*dev_lweight)(), /* hardware line weight */
    void (*dev_erase)(), /* erase graphics screen */
    void (*dev_idle)(), /* switch from graph to alpha mode */
    int (*dev_cursor)(), /* cursor display */
    void (*dev_close)(), /* close device */
    int (*dev_dot)(), /* draw a single pixel dot */
    int (*dev_fill_pt)(), /* draw a filled point */
    int (*dev_fill_polygon)(), /* draw a filled polygon */
    void (*dev_ctype)(), /* set colour of line */
    int (*dev_set_ctype)(), /* set possible colours of lines */
    void (*dev_gflush)(); /* flush graphics */
    void (*dev_page)(); /* start a new page */
    void (*dev_redraw)(); /* redraw the screen, if need be */
} DEVICES;
```

*Note that this is the DEVICES structure at the time of writing; be sure to see that it is still correct when you write your driver!* To add a new device to SM, all you have to do is to write functions to fill as many of the slots in *DEVICES* as possible, add their definitions to ‘sm_declare.h’.

---

12 If the *DV* entry contains an embedded space, only the first word is used to choose a device; the rest is treated as if it was typed as part of a DEVICE command. For example, if the graphcap file contains the entry sva4|svgalib, mode 4:DV=svgalib -m 4:, the command DEVICE sva4 is equivalent to DEVICE svgalib -m 4.
then add an element to the array devices[] in devices.c. After recompiling, SM will recognise your device by the name d_name that you gave it in devices[]. Traditionally the functions have the same name as those given above with the dev replaced by some mnemonic for your new device. You should surround both your driver and the entry in devices[] with #ifdef’s so that all I have to do to totally lose your device is to not #define it to the compiler. In writing your device you may want to use graphcap to give it various pieces of information. This can be done; see the imagen driver for an example.

You should include the file ‘sm_declare.h’ (which automatically includes ‘options.h’) which provides declarations for all SM functions (including prototypes if the compiler supports them), and you should add your own declarations to this file.

If you don’t provide some of the functions, SM will try to emulate them in its software. For example, of your ltype function returns -1, then we will chop your lines for you. There are a set of functions for nodevice that have the correct types, you can use them for functions that you don’t want to provide (e.g. if you don’t support dev_ltype you can use no_ltype). Some of the routines, e.g. dev_char are sometimes passed NULL arguments to inquire if they can provide particular capabilities. In the following paragraphs we discuss all the functions, their arguments, what they do, and what they return.

All coordinates are given in screen units, where the device is 32768 pixels along a side.

**dev_setup(str)** (char *str;)

Open the plotting device. Str contains the rest of the command line, so if the DEVICE command was DEVICE newdev abcde zyxwvut, setup will be passed abcde zyxwvut. If the device can’t be opened for some reason setup should return -1, otherwise 0. Setup has a number of book-keeping responsibilities: setting the value of termout to 1 if the device is a terminal, otherwise 0; setting the value of ldef to the maximum spacing between lines if they are to appear as one thick line rather than a set of parallel ones, (used if we have to emulate LWEIGHT); setting the variables xscreen to pix and yscreen to pix to give the conversion from SCREEN to device coordinates; calling default_ctype with the name of the default colour for lines (e.g. default_ctype("white")). There is no need to look in the ‘.sm’ file for a foreground entry, this is done for you (by set_dev()) after dev_setup returns, but you should deal with any background entry if you feel so inclined. There is a function parse_color that converts a colour name into r, g, and b values (see the sunwindows setup function for an example of its use) that may help. Note that you should not call stg_setup – this was done for you automatically before your setup function was called. No return value.

**dev_enable()**

Enable plotting on the device. For a graphics terminal this means switching from alpha to graphics mode, but may well not be required for other devices. No arguments, no return value.
dev_line(x1,y1,x2,y2) (int x1, y1, x2, y2;)
        Draw a line from (x1,y1) to (x2,y2). No return value.

dev_reloc(x,y) (int x,y;)
        Move the plot marker to (x,y). No return value.

dev_draw(x,y) (int x,y;)
        Draw a line from the current plot marker to (x,y) which becomes the new plot marker.
        No return value.

dev_char(str,x,y) (char *str; int x,y;)
        Write the string at the position (x,y). The position given is just to the left of the first
        character, at about the height of the centre of a capital letter. Return 0 if you support
        hardware characters, otherwise -1 in which case we'll use the software character set
        instead. If str is NULL, this is just an enquiry as to whether the device supports a
        hardware character set. Char is also called (with NULL) whenever the value of expand
        or angle is changed, to allow you to adjust the sizes of cheight and cwidth (the height
        and width of a character in SCREEN units) for a hardware character set, as the sizes of
        hardware sets can be very different from the SM fonts. You should only change cheight
        and cwidth if we are really going to use your hardware characters (expand == 1, angle
        == 0).

dev_ltype(i) (int i;)
        Set the LTYPE to be i, as in the interactive command. Return 0 if you support the ltype
        asked for, otherwise -1. If you can't support a linetype, make sure that you are drawing
        solid lines, so that SM can emulate it for you. LTYPE 10 is special, it is generated by
        the LTYPE ERASE command, and asks you to delete lines as they are drawn, LTYPE 11
        is used to indicate the end of LTYPE ERASE mode.

dev_lweight(lw) (real lw;)
        Set the LWEIGHT to be lw, as in the interactive command. Lines with lweight 0 should
        be the natural thickness of a line on your device, higher lweight lines are usually drawn
        with a thickness of LDEF*lweight in SCREEN coordinates. Return 0 if you support
        the lweight asked for, otherwise -1.

dev_erase()
        Erase the screen. No return value.

dev_idle()
        Return to alpha mode, the opposite of dev_enable(). No return value.

dev_cursor(x,y) (int *x,*y)
        Find the current position of the cursor, if there is one. If there is, the return value is
        the character struck by the user, otherwise return -1. If your device has a mouse, you
        should try to make the buttons correspond to ‘e’, ‘p’, and ‘q’ from left to right. If you
        only have one button, ‘p’ is probably the best choice.
dev_close()

Close the device, the opposite of dev_open(). Note that you should not call stg_close – this is done for you automatically. No return value.

dev_dot(x, y) (int x, y)

Draw a dot at (x, y), (i.e. a real dot, not like the DOT command). You’ll have to do the move to (x, y) yourself. Return 0 if you can draw dots, otherwise -1.

dev_fill_pt(n) (int n ; )

Draw a filled point at the current position. This is the routine that draws PTYPE n 3 points. Remember to allow for EXPAND and ANGLE. Return 0 if you can draw the point, otherwise -1;

dev_fill_polygon(n) (int style; float *x, *y; int n ; )

Draw a filled polygon defined by x and y (a total of n points) in the style style (0: filled; all other values are currently undefined). Return 0 if you can fill polygons in the desired style, otherwise -1. You may get queries with on style with n == 0.

dev_ctype(r, g, b) (int r, g, b ; )

Set the current line colour. The interpretation of (r, g, b) depends on whether you have a dev_set_ctype function. If you don’t, then r, g, and b are the red, green, and blue intensities in the range 0-255. If you do, then r is an index into the array defined by set_ctype and g and b are irrelevant. No return value.

dev_set_ctype(col, n) (COLOR *col; int n ; )

Define a set of colours to be accessed by set_ctype. Col is an array of n elements, each of which consists of 3 unsigned chars (COLOR is defined in sm.h) corresponding to red, green, and blue in the range 0-255. Ctype will be used to access this array to change colours. Return 0 if you do support set_ctype, otherwise -1. If col is NULL this is just an enquiry. If you are asked for more colours than you are prepared to support, you should scale the request in a user transparent way (e.g. if she wants 256 colours, and you are only giving her 128, you should arrange that dev_ctype divides her requests by 2 so it looks as if she got all 256).

dev_gflush()

Flush graphics, update graphics on screen. No return value.

dev_page()

Start a new page. If your device produces hardcopy you should print the current page and start a new one; if you are writing a window system driver you probably should simply raise the window so that it is visible. No return value.

dev_redraw(fildes) (int fd)

Redraw the screen, but only if it needs it. This function is called by getichar() before it tries to read a character from SM’s standard input (file descriptor fd). It is intended for the use of drivers that need to keep an eye on ‘their’ window. For example, the Silicon Graphics driver needs to redraw a window every time that it is moved. Such
device drivers will probably want to poll fildes (e.g. using select()) to see that there really is input before returning; look at the sgi or x11 driver if you want an example. No return value.

If you are still confused, look at some of the hardware drivers that are already available.

A.17.2 Porting to New Machines

Porting to new Unix machines should be relatively simple. If the machine runs BSD Unix the only changes that should be necessary are to the exception handler routines in main.c, to reflect the error conditions signalled by your new machine. For a Sys V Unix, you'll have to edit `options.h' to define SYS_V. Otherwise, your only problems should be hidden bugs which flourish in new architectures.

Otherwise there isn't all that much that I can tell you. SM runs on Unix (BSD and SysV) and VMS machines, and the places where the code is #ifdef'd for those operating systems is your best bet for places where there are machine dependencies. That said, there are a few obvious problem areas.

First consider get1char, which is the routine that reads terminal input. It has to be able to get one character a time from the terminal, and not interpret control characters. This is obviously operating system dependent (CBREAK under 4.3BSD, PASSALL under VMS, ...). Get1char expects to be passed CONTROL-A to start operations, and EOF to end them. Anything else means 'return a character please'. The terminal output functions used by stdgraph are also machine dependent, for example they use QIO calls under VMS.

As mentioned above, the exception handlers try to interpret the exceptions that they receive and this may require a little modification in main.c.

Hardcopy devices need the system() system call to send commands to the operating system, and if you don't have one you are in trouble.

In a few places SM needs to make assumptions about how file names are put together, and these will need changing. On a similar note, some operating systems (e.g. VMS) are very picky about opening files and you may have to be careful. Note the use of the DT graphcap capability to signal particular requirements to the programme.

A machine that didn't use ascii would be rather a nuisance as makeyl assumes that the characters for A-Z are contiguous, and although this could be easily fixed I am not sure that other problems wouldn't arise.

A final rather horrifying thought is that Bison might not compile on a machine that doesn't have YACC as an alternative. I don't know how to fix that, you'd just have to hope for the best, or else run Bison/YACC on a different machine and copy over control.c.
A.18 The System Macro Libraries

This appendix describes the collection of useful macros, written by a variety of people, that are to be found in the default macro directory, i.e. the directory pointed to by the macro entry in your `.sm` file. If ever you write a useful (or simply clever) macro, why not send it to us for inclusion in the next version of SM?

The macros are arranged in a number of files which may be read using the `load` macro. For example, to load the file `fonts` type `load fonts`. To forget a set of definitions, use `unload`. Under Unix, there is a macro `lsm` that can be used to list the contents of macro libraries, e.g. `lsm utils`. It is more-or-less complete depending on the value of `VERBOSE`, just like `LIST MACRO`.

The list that follows gives the name and a one-line synopsis of all the macros in the default files as of the date of this manual. The full text of any macro may be examined via the `help <macroname>` command in SM; the default files may be printed for those who desire a hardcopy.

file `abbrev` in directory `macro`

(This is a file of all unambiguous abbreviations of keywords. It is created using the shell script `abbrev` in the main SM directory. Its use may interfere with cunning macros, and is not recommended).

file `cover` in directory `macro`

cover # draw the cover

file `default` in directory `macro`

batch ## run the history buffer, but don’t delete from history list
bell ## ring terminal bell
calc ## evaluate an expression
cd ## change directories
compatible ## define macros to be compatible with Mongo
declare ## declare a vector $1: declare name size
del ## delete last command from history list
del1 ## don’t put command on history list
echo ## write to terminal
ed ## edit a macro, or the previous one if no argument
edit_all ## edit history buffer
emacs_all ## edit the history list using an external editor.
emacs_hist ## edit the history list using an external editor.
error_handler ## Handle CONTROL-C interrupts
execute # read and execute an SM file of commands (1 per line)
extend_history # Extend history buffer to be of size $1
for ## Repeat a macro while a condition is true, like C’s for(;;). See also while
gripe ## complain to Robert (Unix only)
h ## get help
head ## print the top of the current data (or other) file
hm      ## help with the last macro edited
hv      ## help with variable
insert  ## insert text after line $1
load    ## load macros in default directory
load2   ## load macros in (second) default directory
ls      ## list macros
lsm     ## list macros in a file in default macro directory
lsv     ## list variables
q       ## check, then quit
re      ## macro read
reset_ctype # Reset the default ctypes (except "default")
sav     ## save to a file $1, don’t save from files `$mfiles'
show    ## show current values of various things
startup ## macro invoked upon startup
undef   ## undefine a variable
undo    ## undo [macro] : undo (i.e. erase lines drawn by) macro $1
unload  ## forget macros from a file
unset   # delete a vector
v       ## set verbosity
wr      ## macro write

file ‘demos’ in directory ‘macro’

square   # sum the Fourier series for a square wave, using $1 terms
colours  # draw a circle in a number of colours until ^C stops it
crings   # draw a set of coloured circles
crings2  # draw a set of coloured circles using 256 shades of yellow
gauss_convolve # convolve 2 Gaussians with sigmas $1 and $2
grey_sincos # draw a grey scale image of a sin(x)cos(y) surface
scribble # use cursor to draw a line, and then shade the interior
shading  # draw an ammonite
sundial  # draw a sundial, allowing for the analemma

file ‘fonts’ in directory ‘macro’

fonts    # draw the font table
TeX_defs # draw the ‘‘TeX’’ definitions
make_char # help create a new character

file ‘fourier’ in directory ‘macro’

#
# Macros to make dealing with complex numbers for FFT’s easier
# Assumes that complex vector ‘name’ is represented by two vectors
# called name_r and name_i
#
fft      # Direct FFT: fft name name
ifft     # Inverse FFT: ifft name name
cadd     # Add complex numbers: $1 = $2 + $3
cdiv     # Divide complex numbers: $1 = $2/$3
cmod  # Modulus: $1 = |$2|
cmult # Multiply complex numbers: $1 = $2*$3
csub  # Subtract complex numbers: $1 = $2 - $3
imag  # Imaginary part: $1 = \text{Im}($2)
real  # Real part: $1 = \text{Re}($2)
vcentre # shift a vector so that its 0th element appears in the middle
vcenter # an alias for vcentre

file `images` in directory `macro`

entropy # Find entropy of an image
hist_equalise # Histogram equalise an image
gamma  # Gamma correct an image

file `irregular` in directory `macro`

These macros were written by Gabor Toth, to whom many thanks. They enable you to define an SM IMAGE from 3 vectors, (x,y) and the value z

irregular_image # Set IMAGE from 3 vectors (x,y) and z
trigrid   # Interpolate to the regular grid
trigridtry # Demonstrate the use of trigrid

file `math` in directory `macro`

#
# Written by Daniel Pfenniger (PFENNIGER@obs.unige.ch)
# `A&S` is Abramowitz & Stegun
#
J0     # Bessel func. J0(|x|), A&S, 9.4.1,.3
Y0     # Bessel func. Y0(|x|), |x|>0, A&S, 9.4.2-3
J1     # Bessel func. J1(|x|), A&S, 9.4.4,.6
Y1     # Bessel func. Y1(|x|), |x|>0, A&S, 9.4.5-6
I0     # Modified Bessel func. I0(|x|), A&S, 9.8.1-2
I1     # Modified Bessel func. I1(|x|), A&S, 9.8.3-4
K0     # Modified Bessel func. K0(|x|), |x|>0, A&S, 9.8.5-6
K1     # Modified Bessel func. K1(|x|), |x|>0, A&S, 9.8.7-8
K      # Complete elliptic integral K(m), 0<=m<=1, A&S 17.3.34
E      # Complete elliptic integral E(m), 0<=m<=1, A&S 17.3.36
fresnel # Calculate the Fresnel integrals C, S, and F

file `matrix` in directory `macro`

matrix   # Introduction to matrix utilities
mdeclare # declare $1 to be a $2x$2 square matrix
mdimen   # print matrix $1’s dimension
mprint   # print the matrix $1 (given as $1_0 \ $1_1 etc -- see minv)
madd     # set matrix $1 equal to $2+$3
minv     # Quick matrix inversion, done in place.
mset     # set matrix $1 equal to $2
Appendix A: Appendices

**mmult** # set matrix $1$ equal to $2*3$
**mmult_c** # set matrix $1$ equal to $2*3$ where $3$ is a scalar
**mmult_v** # set vector $1$ equal to $2*3$ where $3$ is a vector
**mmult_vT** # set vector $1$ equal to $2^T*3$ where $2$ is a vector
**mtrans** # set matrix $1$ equal to $2^T$
**mprint** # print the vector $1$

file ‘mongo’ in directory ‘macro’

(omitting those that are simply abbreviations, like **ang**)

data ## set data file
device ## set device
draw ## draw, accepting expressions
define ## define vector error_col as error vector
end ## quit, not on history
erase ## erase screen, not on history
list ## list history, not on history
hard ## make a hardcopy of what you type (or get by history)
hardcopy ## close the old device and set dev type to 0
hcopy ## hcopy [printer] [l1] [l2]: Make hardcopy of playback buffer
hmacro ## hmacro [macro] [printer]: make hardcopy of ‘macro’ on ‘printer’
identification ## write an id to the top right hand corner of screen
input ## execute an Mongo file
mongo ## make SM resemble Mongo as closely as possible
pointcolumn ## set point column (Mongo)
playback ## define "all" from buffer, and run it
read_all ## read a macro file, putting ‘all’ onto the history buffer
read_hist ## read history from a file
read_old ## read an Mongo file onto the history buffer
rel ## relocate, accepting expressions
save_all ## write the playback list to a file (use sav instead)
terminal ## device
toplabel ## put label at top of plot
xcolumn ## read a column into vector x (Mongo)
xlogarithm ## take log of vector x (Mongo)
ycolumn ## read a column into y
ylogarithm ## take log of y

file ‘project’ in directory ‘macro’

Miscellaneous projections (e.g. equal area). Contributed by Michael Strauss.
aitooff ## convert l and b to x y in Aitoff coordinates
aitoff1 ## Convert l and b to x y in reverse Aitoff coordinates
aitoffdec ## Draw a line of constant declination in an Aitoff plot
aitoffdec1 ## Draw a line of constant declination in a reverse Aitoff plot
aitoffgrid ## Put up equal area grid in Aitoff
aitoffgrid1 ## Puts up equal area grid in Aitoff. Reverse sense
calc_l ## Calculates r, l and b given x, y, and z
circle_exclude ## After circleplot, draws regions excluded in latitude
circlelabel  # Draw axes for a redshift circleplot
circleplot  # Plot redshift points; requires circlelabel
eqgal  # Usage: ra dec l b; Convert (ra, dec) to (l,b).
galeq  # Usage: galeq l b ra dec. Convert (l,b) to (ra, dec)
galgrid  # Puts up equal area grid
galplot  # Usage: galplot ra dec l b
galpoints  # Plot points on an equal area grid; galpoints l b
gstrans  # Convert supergalactic to galactic coordinates
hemiconvert  # Convert from l b to x y for hemisphere plotting
hemidec  # Draw a line of constant declination on a pair of
hemiplot  # Sky plot in two hemispheres, equal area
invaitoff  # Convert x y in Aitoff coordinates to l, b
pielabel  # Draw axes for a redshift pieplot
pieplot  # Plot redshift points; requires pielabel
radtick  # Put tick marks on a radial axis
sgtrans  # Convert galactic to supergalactic coordinates

cgauss  # evaluate a cumulated Gaussian distribution: N($mean,$sig)
cuniform  # evaluate a cumulated uniform distribution, $mean,$sig
chisq  # Return chi^2 distribution of vector $1 with $2 dof
draw_KS  # Draw a cumulated curve, for looking at KS statistics
erfc  # calculate complementary error function erfc($1)
factorial  # Use Stirling's formula to calculate a factorial ($1)!
gauss  # evaluate a Gaussian: N($mean,$sig)
gaussdev  # return a N(0,1) random vector
linfit  # linear least squares fit for any number of parameters
log_fac  # Use Stirling's formula to calculate a log factorial.
lsq  # do a least squares fit to a set of vectors
lsq2  # do a least squares fit to a set of vectors, errors in x and y
prob_chisq  # probability of getting a given value of chi^2
prob_KS  # probability of getting a given value of the K-S statistic
prob_wilc  # return probability in $$2 that x exceeds $1 from Wilcoxon
rxy  # find Pearson Correlation Coefficient for two vectors
smirnov1  # calculate 1 sided Kolmogorov-Smirnov statistic for vector
smirnov2  # calculate 2 sided Kolmogorov-Smirnov statistic for vectors
spear  # calculate Spearman rank correlation coefficient for 2 vectors
stats  # stats vector mean sigma kurtosis: calculate $mean $sigma etc
stats2  # stats vector weights mean sigma kurtosis
stats_med  # stats_med vector median SIQR: calc $median $SIQR from vector
wilcoxon  # calculate Wilcoxon statistic for 2 vectors
wlsq  # do a weighted least squares fit to a set of vectors

Equivalents for all SM trig functions, taking degree arguments. Names add an extra 'd' (e.g. sind)
file ‘utils’ in directory ‘macro’

alpha_poi  # alpha_poi x y z. Like poi x y, but use z as labels for points
arc        # the arclength along the curve (\$1,\$2), e.g. set v=arc(x,y)
age         # use the cursor to define an arrow.
barhist     # draw a bar histogram
boxit       # use the cursor to define a box, and draw it
circle      # draw a circle, centre (\$1,\$2) radius \$3
cumulate    # find the cumulative distribution of \$1 in \$2
draw_arrow  # draw an arrow from (\$1,\$2) to (\$3,\$4)
draw_box    # draw a box, defined by two corners
tune_x      # draw x-error bars: error x y size
tune_y      # draw y-error bars: error x y size
gem_hist    # get_hist input output-x output-y base top width
gauss      # evaluate a Gaussian : N($mean,$sig)
get         # syntax: get i j. Read a column from a file
glevels    # Set grey levels. Usage: glevels expr
greyscale    # Draw a grey-scale image.
  # Usage: greyscale [npix npy maxweight dmargin]
info        # Get help about a command from SM’s info files
interp      # Linearly interpolate $3 into (\$1,\$2), giving $4
interp2     # Linearly interpolate $3 into (\$1,\$2), giving $4
is_file     # Return true if file \$1 exists
is_macro    # Return true if \$1 is a macro
is_set      # define variable \$\$1 if the \$3'rd bit is set in \$2
is_vector   # Return true if \$1 is a vector
logerr      # syntax: logerr x y error, where y is logged, and error isn’t
mconcat     # Concatenate 2 macros, optionally renaming result
number      # convert a string vector to an arithmetic one
pairs       # pairs x1 y1 x2 y2. connect (x1,y1) to (x2,y2)
polar       # draw a circle as an ‘axis’ for polar coordinates
pmatrix     # print the matrix \$1
puts        # Draw a line of text, then move to the start of the next line
qminv       # Quick matrix inversion, done in place
repeated    # Return an array that is true for repeated elements in \$1
reverse     # reverse the order of a vector
save_vec    # put the definition of a vector onto the history list
set_window  # cycle through all available windows
shade_box   # shade a box, spacing \$1, defined by two corners
shed        # shade region between x y and x2 y2 with n lines
simp        # Simpson’s rule integration: simp answer x y
smooth      # boxcar smooth a vector
smooth2     # smooth a vector with a given filter
smooth3     # smooth a vector with a given filter omitting points
2dhistogram # convert the current image to a 2-d histogram
thin        # create a "thinned" version of a vector for plotting points
thin2       # "thin" the end of a vector
thin3       # "thin" the central portion of a vector
uniq        # Remove duplicate elements of \$1, e.g. u = uniq(x)
upper       # define a variable giving an ‘upper limit’ symbol
vecminmax   # find the minimum and maximum of a vector
vfield  # plot a vector field: vfield x y len angle
vfield2 # plot a vector field, vfield x y len angle (len in x-axis units)
vfield3 # plot a vector field: vfield x y len angle (len in y-axis units)
vfield4 # Vector field at points x, y; components vx vy
vfield5 # Vector field at points x, y; components vx vy scaled by f

A.19 Tips for Mongo Users

A.19.1 Differences from Mongo

SM differs in a number of ways from Mongo, and these fall into three groups: those which are enhancements, those which are generalisations, and those which are simply incompatibilities. We do not feel that there is a fourth group for degradations. For those users of Mongo intimidated by change, we note that in most cases it is possible to ignore the enhancements by using a macro presented in the next section. This macro redefines commands to reproduce the old syntax; for example limits is defined to mean LIMITS x y. It is also possible to read Mongo files using the READ OLD command, and the macros input and read_old based upon it. The following list of enhancements in not complete; See the distribution notes from the current release of SM.

Enhancements:

Any number of vectors may be defined.
Vectors may be manipulated arithmetically.
Vectors are named.
Vectors may be defined from the keyboard using DO loops or expressions.
Vectors may be defined using the cursor.
Any vector may be used for plotting.
Any vector may be used for the PTYPE or ERRORBAR commands.
A history feature is implemented.
The playback buffer may be edited.
Macros may be defined from the keyboard, and edited.
A DO construct is available.
A FOREACH construct is available.
Character strings may be read from a file and used freely as labels or names.
Data may be read from rows as well as columns in files.
Only those parts of a vector satisfying a logical condition need be plotted.
Vectors may be sorted or fit with splines.
Macros exist for doing least square fit to sets of points, constructing cumulative distributions and histograms, drawing circles, and shading regions.
All devices have the same range of device coordinates, 0-32767.
The entire SM environment may be saved for later resumption with SAVE and RESTORE.
The special variable $date expands to the current date and time.
You can define private point types.

There are also a few incompatibilities:
DEFINE is used to define variables; macros are defined using MACRO.

Macro arguments must be declared, and are referred to as $n,
not &n.

The form LIMITS is not supported (it's meaningless); use
LIMITS x y, or the macro lim, mentioned above.
(But note that READ OLD allows for these, and makes suitable changes.)

WINDOW now takes 4 arguments.

A.19.2 The READ OLD command

READ OLD reads a Mongo file, converts its contents to a form acceptable to SM, and defines them as a macro. Any macro definition (i.e. from a line beginning def to a line beginning end) is converted to the SM form (i.e. `$s' not `&s') and defined. The commands CONNECT, HISTOGRAM, LIMITS, and POINTS are converted to LIMITS x y, and so forth. ERRORBAR, ECOLUMN, and WINDOWS are also converted. READ OLD will fail if the Mongo file contains abbreviations such as xc for XCOLUMN, then your only hope is to define the same abbreviations. In many cases this will have already been done, for instance xc expands to read x. Comments (beginning !) are optionally converted to standard SM # comments (depending on how the file `read_old.c' was compiled.)

Note that it is advisable to convert these old Mongo macro files to SM macros, to enable you to take advantage of SM's features. You can do this by simply using READ OLD to read them into SM, and then MACRO WRITE or SAVE to write the converted macro out to disk.

There is also a macro equivalent of the old INPUT command.

```
input 1  ## read and execute a Mongo (not SM) file
   READ OLD _temp $1
   _temp
   MACRO _temp DELETE
```

A.19.3 The compatibility macro

This version of compatibility is more complete than in pre-version 2 SM, it also conflicts more strongly with normal SM operations.

The macro compatibility defines mimics for the Mongo commands which assume that the only vectors are x and y. We strongly recommend that you do not use this macro! If you want to use it anyway, commands like limits alpha beta will give syntax errors. You can turn compatibility mode off again with compatibility 0. The macro itself is a little complicated, it turns off the special meaning of (e.g.) limits, and replaces it with a macro that reproduces the old behaviour, in this case LIMITS x y. The new definitions are in the file `compatible' in the default macro directory, as specified in your `.sm' file. At the time of writing, the commands connect, errorbar,
histogram, limits, list, points, read, and window are redefined to reproduce the old syntax. In addition, help is defined to not appear on your history buffer, and define is defined to create macros interactively. You might also be interested in other redefinitions of commands (e.g. list to mean list the playback buffer), if so look at ‘overloading’ in the index. It should be clear that this set of definitions could thoroughly confuse SM if you try to take advantage of its features; in the realm of compatibility mode, it is strictly caveat emptor.

```bash
compatible 11  ## define macros to be compatible with Mongo
   ## If the argument is non-zero or omitted,
   ## compatibility mode is turned on.
   ## note that some of these make it hard to use regular SM!
   if($?1 == 0) {
       compatible 1
       RETURN
   }
   if($1 == 0) {
       MACRO DELETE "$!macro"compatible
   }
FOREACH w { connect define errorbar help histogram limits \
   list points read window write } {
   OVERLOAD $w $1
}
   if($1) {
       MACRO READ "$!macro"compatible
   }
   # So newline will end IF statement
```

A.20 SM’s Fonts

These are a sub-set of the well-known Hershey fonts\textsuperscript{13} and the available characters are listed in the following table, which were generated from within SM by saying \texttt{load fonts fonts}.

For details on SM’s implementation of \LaTeX{} and the ‘traditional’ style see the section in the main body of this manual (see \texttt{(undefined)} [Labels], page \texttt{(undefined)}).

The characters in a font are specified using a programme \texttt{readfonts} which you can use to make binary font files from the list of Hershey characters, using an index file to specify what character should go where. The binary fonts file also specifies which \LaTeX{} ‘definitions’ are available (e.g. \texttt{\alpha}). The first 4 bytes of the file are an integer (in binary) that specifies the format of the file;

\textsuperscript{13} created by Dr. A. V. Hershey at the U. S. National Bureau of Standards and illustrated in National Bureau of Standards publication NBS SP-24. The format used in the hershey.uc.dat file was originally due to James Hurt at Cognition, Inc., 900 Technology Park Drive, Billerica, MA 01821. It may be converted to any format except the format distributed by the U. S. NTIS (whatever it may be). We have to tell you all this for copyright reasons, but as distributed the fonts are in the public domain.
when the format is changed in an incompatible way this number if changed and you will have to rebuild your font files (‘make fonts’).

The default font table is illustrated at the end of this appendix. Which font file you want to use is specified as the fonts entry in your ‘.sm’ file.\textsuperscript{14} The fonts.bin fonts have been cleaned up a bit for version 2.0 of SM, although the order of characters in the greek and roman fonts is unchanged. There is a new font, ‘Old English’ or \o or \oe, and a good number of new characters are provided. Neither of these fonts supports the ‘private’ fonts, that is there in case users desperately need something, when they can make their own binary font file. For example, there is a set of Hershey oriental fonts that can be used to help SM write Japanese (see (undefined) [Japanese], page (undefined)).

The complete list of (occidental) Hershey characters is given in a file called hershey_oc.dat, and is in the public domain. Each character is specified by a number in the first 5 columns, then a number of strokes in the next 3, then pairs of letters in the remaining columns up to 72, and in as many 72 character lines as are needed. (Annoyingly, if a line consists of exactly 72 characters, the next must be left blank). Each pair of characters consists of a coordinate, with the origin at (R,R), and the y axis pointing down. A ‘ ’ indicates that the next point is a move, otherwise just connect the dots. The very first pair is different, as it specifies the left and right spacing for the character. If this isn’t clear, try drawing a few characters on graph paper, character 2001 (roman A) for example. There are a few characters that have traditionally been available in Mongo that are not in the Hershey set, these have been added to the end of the ‘hershey_oc.dat’ file, plus a few that we thought deserved adding.

If you want to create your own characters, the macro make_char in ‘fonts’ (i.e. load fonts make_char) might help. It uses the cursor to make a string that is (nearly) in the correct form for inclusion in ‘hershey_oc.dat’.

The programme read_fonts reads this file, an ‘index’ file that specifies the characters to be put into the fonts, and a list of \TeX definitions. The index file consists of character numbers, or ranges consisting of two numbers separated by a minus sign. Comments go from the character # to end of line. Each font consists of 96 characters in ascii order, and fonts appear in the index in the order rm, gr, sc, ti, oe, and then the various private fonts (privateA, privateB, . . . , privateG.). You can also use cat_fonts to concatenate binary font files prepared with read_fonts.

The format of the \TeX definition file is that each definition has a line to itself, lines starting with a # are comments. A line consists of a name, some whitespace, the number of arguments (optional, defaults to zero), the name of the font to use, a single white-space character, and the value of the definition to the end of the line; you can continue onto another line by putting a \ at the end of the line. You can use any of the normal font specifications, or cu which means use the current font.

\textsuperscript{14} It’s possible to resurrect the font table used by pre-2.0 versions of SM, using the index file ‘old_font_index’
For example

\begin{verbatim}
alpha gr a
alsoalpha 0 cu \gr a
alphatoo 1 gr \#1a
\end{verbatim}

defines \texttt{\textbackslash alpha} the conventional way as the character \texttt{a} in the greek font, then defines \texttt{alsoalpha} in a less efficient way (by specifying the current font, then explicitly switching to greek), then defines \texttt{alphatoo} as a large $\alpha$, used as \texttt{\textbackslash alphatoo5}. There’s no reason why your definitions can’t be reasonably complicated, see for example the definition of \texttt{\TeX}.

If the number of arguments is given as -1 the \texttt{\TeX} symbol will be interpreted as an alias for the specified font, for example the \texttt{\TeX} definition file begins

\begin{verbatim}
katakana -1 privateA
hiragana -1 privateB
\end{verbatim}

to make \texttt{\textbackslash katakana} change to the \texttt{privateA} font.

The main Makefile prepares your binary font file for you. There is also a programme \texttt{cat\_fonts} that can be used to concatenate two or more binary fonts files; an example is given in the section on Japanese fonts ((\texttt{\textbackslash undefined}) [Japanese], page (\texttt{\textbackslash undefined})).
Select a device and say ‘load fonts \TeX\_defs’ to make this page
Select a device and say ‘load fonts fonts’ to make this page

It is also possible to build SM fonts for other languages:

A.21 Using SM to write Japanese

SM is currently able to use either katakana or hiragana fonts, but no kanji are yet supported. The order of characters in the fonts is likely to change, based on the desires of the users. Please let me know what you want.

As distributed, the Japanese font tables aren’t built. To make them, say `make jfonts.bin` in the toplevel SM directory, and ensure that your `/.sm` file sets `fonts` correctly. The Japanese characters are available as `\hiragana` and `\katakana`. You can list the characters available with `load fonts jTeX_fonts`.

One question is whether `\katakana 2` should print an Arabic (western) or a Japanese two; I am open to suggestions.

There are a variety of kanji characters present, but no easy way to select them. If someone would like to donate a table of the correspondence between some accepted ascii encoding and the available characters, I will ensure that the character encoded as `AB` os available as (say) `\kanjiAB`, and provide a programme to generate such codes from the output of at least one popular word processor, expecting the user to cut-and-paste the result. Of course, it’d be quicker if you did it for me!
General Index

There is a separate index for graphcap capabilities, see (undefined) [Graphcap Index], page (undefined).

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