Linux for Mathematics Teachers

Geoffrey Aldis (11/12/2000)
School of Mathematics and Statistics
Australian Defence Force Academy

Abstract

Current Linux distributions bundle in many applications that could be useful for mathematics teaching. A short Linux background is given, followed by a description of some of the mathematical packages. Testing the software indicates that the syntax of some is very similar to well-known commercial programs. Students can easily transport the skills they learn from the Linux programs, and teachers can make use of the resources already written for the commercial programs. A discussion of the plusses and minuses of running PCs in Linux for teaching is given, followed by an appendix of test commands and useful Web pages.

1 Introduction

This article grew out of my exploration of Linux. SuSE Linux was introduced as an operating system for our School PCs in July 2000. There appeared to be so much mathematical software installed that I decided to take a closer look and to share the results of that exploration. Our School pays to use commercial application programs such as Maple, Mathematica, MATLAB and SPlus. They are very powerful programs and efficient for compute-intensive research problems. For teaching, the demands need not be so great, but we like to show students the tools we actually use. It would cost High Schools and Colleges a lot of money to use the same commercial packages in their teaching. As shown in this article, Linux offers a simple way for schools to install a suite of high quality mathematical software at almost no cost.

Linux is illustrated here with SuSE Linux, since that is what I use at ADFA. It is Europe's most popular Linux distribution and with 1900 packages in SuSE 7.0 Professional it is big, and a good choice for serious scientific work. What is said in the article will also apply to Red Hat, Mandrake, and other popular Linux distributions. The latest releases of the different distributions use the same Linux kernel. What makes them different is the special system administration tools they use (though many will still be the same), and the selection of packages they include. Distributions that handle packages in the popular rpm (Red Hat package manager) format are very compatible. Installing new packages or upgrading or deleting existing packages is then a simple process. The article is written from a PC viewpoint, but Mac PowerPC versions are available for some Linux distributions (including SuSE).

First, some reasons for the recent rise of Linux will be considered. Then a brief description of the Linux desktop environment is given, together with how a machine can be run loaded with both Linux and Microsoft Windows. Mathematical software is then described. The list of software considered in this article is incomplete and it simply reflects my guess at what would be useful. The readers will be better judges of what will work or not at school. This is followed by an attempt to identify the plusses and minuses of using Linux software for teaching. There is a fair amount of guesswork here too, and the author would like to know if teachers find important points were missed, or if emphases were wrong. Finally, an appendix has some commands to try if you test-run the programs, and some Web page references are given.

2 The rise of Linux

Linux, the PC version of Unix, originated in 1991 from the efforts of a Finnish PhD student, Linus Torvalds. Being open source software, it is now developed by a multitude of contributers, who are keen to eliminate bugs and to improve it. There are some very, very talented people writing Linux software. Linux gains in popularity as PCs get progressively faster and users look for alternatives to Microsoft's apparent monopoly of PC software.

Things that make Linux attractive and increase its market share: (i) it is free – the cost is usually for the distribution media and/or printed manuals; (ii) it is now easier to install and comes with a user-friendly desktop environment; (iii) Linux can be set up in dual-boot mode with Windows. Hard disks are now large enough that availability of disk space is not a restriction; (iv) Linux is not plagued by viruses; (v) there is a huge range of software available for Linux (but new release games are usually not available for Linux); (vi) Open Source software means bugs get fixed. The GNU organisation (URL given in the Appendix) produces high quality compilers and other software. These are a significant part of Linux; (vii) Linux has improved its multimedia functions and its handling of peripherals such as printers and scanners.

3 Running Linux

For modern PCs a user would usually run Linux in X-Windows mode. This gives the familiar graphical display, with point and click using windows, menus, icons and mouse. On top of that Linux has a choice of Desktop Managers. These determine the 'look and feel' of a desktop. The KDE (K Desktop Environment) is a popular example. It comes with a set of coordinated programs to handle mail, file display, editing and so on. The desktop environment is customisable, no matter which desktop manager is chosen. Users familiar with MS Windows should have no trouble with the KDE desktop, but like all new systems, some time is needed for a user to try all the simple tasks and to feel 'at home'.

A user can do everything with the mouse, but those familiar with Unix will also want to use a terminal window to type in commands. This should not be seen as a throwback to primitive times. Linux (Unix) commands are very powerful. Most come with a set of optional flags which allow each command to have a wide range of actions. When a user pipes two commands together (makes the output from one command the input to the next) what can be achieved is truly astonishing. The frustration most Unix users feel when working in Windows stems in part from having to slow down and do things in small steps.

When a PC is set up as dual-boot between Linux and Windows, one of these must be chosen as the default operating system. After being turned on a PC will do the first steps of boot-up and then pause for a few seconds. The user may then select Linux or Windows. If the boot program receives no keyboard input, it proceeds into the default.

If a user is in Windows/Linux mode and wishes to enter Linux/Windows mode, they need to shutdown the PC and restart into Linux/Windows. There will typically be a delay of one or two minutes. This is inconvenient, but usually only if it needs to be done frequently. In Linux it is possible to see the Windows area of the hard disk. A user can edit, move, copy or delete Windows files in Linux. The Windows side is more limited. Windows cannot see into the Linux areas of a hard disk. If a user wants to have both operating systems available together, then programs such as **VMWare** can be purchased. A fast PC is needed for performance to be acceptable in this mode.

4 Mathematical software

Linux is a veritable Aladdin's cave of software. A considerable amount of time is needed to search through the packages in SuSE. The Freshmeat site (URL given in Appendix) is a huge repository of Linux software. New packages are reviewed and classified there and made available for download.

The following packages are included in the SuSE 7.0 Professional edition. They are examples of packages that could be useful to mathematics teachers. A reference to the full list of SuSE packages is given in the Appendix, as are Webpages for some of the packages..

Curve and surface plotting

The package **xgfe** is a simple interactive curve and surface plotter, based on **gnuplot**. Sometimes simplicity is a virtue. **Xgfe** requires almost no training to use and allows typical student plots to be obtained quickly. **Kplot3d** also allows interactive surface plotting. A number of curve plotters and scientific calculators are available. Some of the following packages also plot objects in 2D and 3D.

Computer algebra system

Mupad (X version, **xmupad**) is a symbolic algebra package with syntax like the commerical package **Maple**. It can prime factorise a number, solve equations, differentiate, do indefinite and definite integration, manipulate matrices, plot functions and surfaces, solve differential equations, and much more. Typing ?demo brings up a guided tour and a 557 page user manual. For teaching, **xmupad** may be the most useful of the packages considered here. There is a lot of teaching material available for **Maple** which would also apply to **xmupad**.

MATLAB substitutes

Octave is ideal for numerical linear algebra (matrix manipulations, etc). It has a syntax very similar to **MATLAB**'s. When I tested it with a **MATLAB** tutorial (of an early version of **MATLAB**) **octave** did almost everything without complaint. It is light on optimisation and plotting compared to **MATLAB**. **Octave** can solve differential equations numerically. A user guide is available from the SuSE 'howto' list. **Scilab** is also similar to **MATLAB** in scope. It is more powerful than **octave**, having more features, but the syntax is not as close to **MATLAB** as **octave** is. A translator is included to convert command scripts written for **MATLAB** to **scilab**.

Statistics

R is a statistical package similar to **S**. **SPlus**, the better-known commercial version of **S**, has a full GUI interface. **R** is quite powerful at statistical analysis of data and data plotting (box-whisker plots, scattergrams, histograms, etc). Statisticians often write command scripts to process data in **S** or **SPlus**. **R** can handle these. There is currently no user manual for **R**. Users are encouraged to refer to manuals for **S**. Other statistical packages are available.

Fractals

There are a number of Linux packages which allow the user to explore fractals. With **xaos** a user can zoom into the Mandelbrot set in a continuous motion. The user can direct the trajectory while zooming. There is a choice of fractals and a number of options (xaos -help). Other fractal packages include **xfractint**, **kfract** and **terraform**. The latter is used to construct fractal landscapes.

Interactive geometry

Drgeo can be used to explore geometry interactively. It is a new addition in SuSE 7.0 and has a few rough edges. The French documentation (when it is finally found) will add further mystery for many. However it is worth persevering with. The user can lay down a set of points, and use the points to construct lines, line segments and circles. The coordinates of points, lengths of line segments and equations of circles and lines can be displayed. Points can be moved in real time and coordinates, lengths and equations update dynamically. The user can ask **drgeo** to do other tasks, such as to find the midpoint of a line segment or to draw a perpendicular. These will also update when points are moved. Visual 'proofs' of many geometric theorems can be developed quickly with **drgeo**.

Stereograms

The package **kblinsel** will generate a stereogram (a Magic Eye picture) from a user-supplied image file.

Travelling salesman optimiser

Ktsp can be used to solve travelling salesman problems (to optimise the route around a set of locations).

Compilers

The GNU Foundation (URL supplied later) handle a number of high quality compilers, and many of these are available in SuSE. Languages include C/C^{++}, Pascal, Basic(interpreter), Java and Fortran 77 (with some F90 features). Some Linux editors (such as **xemacs**) have features which go part of the way towards an 'integrated development environment' for programmers.

Mathematical word processing

Mathematical equations in Microsoft Word started off looking pretty horrible and they haven't improved over the years. LaTeX (the popular version of TeX) is commonly used by university mathematics departments to achieve publication quality output. Linux mathematical typesetting is mostly based on LaTeX. The SuSE distribution includes a large amount of LaTeX documentation, including guides suitable for a new user. Figures and plots are usually made in PostScript to enable easy incorporation into documents. PostScript objects can be scaled without loss of information. PostScript figures and plots can be generated by applications, or by drawing packages such as **xfig**. The **xemacs** editor has syntax highlighting and it incorporates document previewers. **Lyx** is an editor that can make generation of LaTeX documents easier in a number of ways. LaTeX is normally written by typing markup commands into a document. Experienced LaTeX users find this faster than retrieving symbols from a menu. **Lyx** provides menus for those who prefer that method of entry. Star Office (see next) allows equations to appear in the Microsoft style. Examples of LaTeX output follow.

$$\int_0^\infty \mathrm{e}^{-x^2 \sin x}\, dx, \quad A = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix}$$

Spreadsheets

There are a number of office suites available in Linux. **Star Office** is promoted by Sun as a free alternative to the Microsoft Office suite. The spreadsheet program can import from and export to MS-Excel. There are minor incompatibilities between Star Office and MS-Office, but Star Office is a powerful suite in its own right. Future releases should strengthen its position. Other good spreadsheets are available in Linux.

5 Plusses and minuses of Linux for teaching

First, the plusses: Clearly there is a lot of software available in Linux which does not have to be purchased or licensed for school or home use.[1] Extra packages can be easily

[1] Some of the 1900 packages in SuSE 7.0 Professional edition are demonstration versions of commercial software. They are clearly marked in the category 'pay' and are in the minority. There are also some anomolies. Star Office does not have a full GNU Public Licence, and so it appears in the pay section. For normal users, there is effectively no restriction on Star Office. (Do you have more than 8 CPUs in your PC?)

added, particularly if they are available in the rpm format. Linux programs are mostly well-documented. Documentation is put on the PC at install time. There are also Websites devoted to packages and newsgroups handle user problems.

Some of the programs discussed above have Windows or Mac versions. Mupad, for example, is available on a large number of platforms, but only a light version is available for free use on Windows. A Windows version of drgeo is available but development is proceeding through the Linux version. Linux, the GNU Organisation, and the Open Source community are all linked in their desire to make high quality software freely available. It is no surprise that so much free software is bundled in with a Linux distribution. By using Linux, a school could avoid the need to load and maintain extra software from many different sources.

Although the Linux programs are not identical to commercial programs, in many cases the syntax is very close indeed. Skills learnt with these programs would pass over immediately to the commercial programs which students may use later at university or in their career. The closeness of syntax would also enable teachers to make use of the large number of examples and amount of teaching material available for the commercial programs.

Like Unix, Linux has good file protection built in. Students are unlikely to corrupt system files or other students' work. The viruses which cause havoc with Windows PCs are ineffective when Linux is running. Linux can run effectively on quite old PCs. Memory (RAM) has a strong impact on Linux performance. 64 Mb is probably a useful minimum and a PC with 128 Mb should run well. Linux with a reasonable set of applications should fit into 2 Gb of hard disk space, and a little more would be comfortable.

It is not necessary to devote a PC entirely to Linux. A hard disk can be repartitioned, with Windows occupying part and Linux the other part. To switch from one operating system to the other (without purchasing **VMware**) it is necessary to reboot. This involves a delay of a minute or two. However Windows files can be seen and worked on in Linux. Mac PowerPC versions of Linux are also available.

An important minus is that only some staff would be familiar with Linux. There is a LOT of documentation installed with Linux, and time is needed for users to become comfortable with running it. (Students sitting at a Linux PC, on the other hand, should be able to work with a minimum of instruction. The application of interest can be visible as an icon on the desktop, and once started the application could be used for a limited task with just a few commands.) Another significant minus is that Linux requires some time to install and customise. Small site-specific problems are likely in the early stages. These problems could be overcome by a member of staff who had a special interest in Linux. Help is available from the distributions (like SuSE) and from newsgroups on the World Wide Web.

Running PCs in Linux would enable a school to use high-quality applications software at very low cost. Most of this application software would be included in the distribution and would not have to be handled separately. The most significant negative could be the time required to set Linux up and to explore it. This should not be a problem for an IT professional, since Linux is recognisable as a version of Unix. However for a teacher with limited time for computing, and without Unix experience, it could be difficult. It should be stressed that Linux is not intrinsically difficult, but time is needed for a novice to become proficient at administering it. If enough mathematics departments were interested in Linux software it could be useful for a school or regional authority to try for a development grant related to implementing Linux in a school setting. With some expertise available, the time needed for an initial customisation could be reduced and each school could avoid 'reinventing the wheel'.

6 Appendix

The following commands are included as suggestions when test-running some Linux packages. Text after "//" are comments, ">>" and ">" are prompts.

xmupad

```
>> Factor(2378);  // Prime factors
>> DIGITS := 50;  // More precision in the calculations
>> float(PI/E);   // Show a calculation to 50 digit accuracy
>> unassign(DIGITS):  // Set accuracy back to default
>> f := (x-1)^2/(x-2) + a;  // Define an expression
>> f1 := diff(f,x); // First derivative
>> solve(f1=0, x);  // Find x where derivative is zero
>> a := 0; plotfunc(f1, x=-2..5) // Plot the derivative against x
>> int(f, x=3..5);  // Definite integral
>> float(%); // Give numerical value of previous
>> limit((1+1/n)^n, n=infinity); // famous limit -> e
>> solve({x+y=5, x-y=2},{x,y});  // solve simultaneous eqns
>> series(f,x=1,8);  // expand f in a series, keep 8 terms
>> simplify((x-1)^10 - 8*x^5);  // expand and simplify
>> g := sinh(2*y)*cos(2*x); // an expression with common functions
>> diff(g,x,x) + diff(g,y,y);  // shows g solution of Laplaces eqn
```

octave

```
> A = [1 2 3; 4 5 6; 7 8 0]  // define matrix A
> det(A)   // determinant of A
> eig(A)   // eigenvalues of A
> [u,v] = eig(A)  // eigenvalues and eigenvectors of A
> x = -1:0.1:10;  // x is vector -1 -0.9 -0.8 ... 10
> plot(sin(x))    // plot the sin function over x range
> exit
>
> function xdot = vdpol(x,t)  // ode example. (NB x and t reversal)
> xdot = zeros(2,1);
> xdot(1) = x(1).*(1-x(2).^2)-x(2);
> xdot(2) = x(1);
```

```
> end
> x0 = [0 0.25]';
> t = linspace(0, 20, 100);
> y = lsode("vdpol", x0, t);
> plot(t,y)    // shows the solution to this Van der Pol problem.
```

R

```
> demo()    // shows list of demos
> demo(graphics)  // start the graphics demo
> q()       // leave R
```

SuSE Linux URLs

http://www.suse.de/en

http://www.suse.de/en/produkte/susesoft/linux/Pakete_pers

http://www.suse.de/en/produkte/susesoft/linux/Pakete_prof

Other URLs

http://www.everythinglinux.com.au (Australian shop with everything...)

http://www.linuxcentral.com (Another big Linux resource)

http://freshmeat.net (Latest Linux packages)

http://www.gnu.org (GNU software and manuals)

http://www.mupad.de (Mupad's home page)

http://www.che.wisc.edu/octave/octave.html (octave's home page)

http://www-rocq.inria.fr/scilab (scilab's home page)

http://ofset.sourceforge.net/drgeo/ (info on drgeo)