MAPLE plot quality and PostScript conformance

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1 Introduction

The University of Utah Mathematics Department has had a long involvement with MAPLE, going back to at least 1984, when MAPLE was written in Margay, a preprocessor to the B language (and the ancestor of the now widely-used C language), and ran under TOPS-20 on our DECsystem-20/40. More than a decade ago, the campus software site-license committee that I co-founded chose to license MAPLE for unlimited campus-wide use on all supported architectures, and the University of Utah continues to do so today.

MAPLE is in wide use throughout our science and engineering communities, and also in the Colleges of Business, Humanities, Medicine, and Nursing, and many courses use it. For the Mathematics Department and the Physics Department, a survey of license-manager log files in a report that I wrote in the summer of 2001 showed an average of more than 10,000 invocations per month of MAPLE versions 6 and 7. Those two departments collectively have more than 7400 active user accounts today, with peaks of 12,000 to 15,000 active and inactive accounts over the past several years.

We have a very strong commitment to MAPLE at the University of Utah, using it in teaching and research, and also for professional journal and book publications. It is of extreme concern to us to see the serious deterioration in the quality of MAPLE graphics output that was experienced when MAPLE 9.0 was installed in our Mathematics Department on 31-Oct-2003.

As a historical footnote, John Warnock, the inventor of PostScript and co-founder of Adobe Systems, Inc., has three degrees in mathematics from the University of Utah, two of them from my Department. The genesis of PostScript can be traced back to a fusion of mathematics and computer graphics at this University, then to his work at Evans and Sutherland Corporation, and later, at Xerox PARC.

I have personally been involved in PostScript programming since the first PostScript-based printer, the Apple LaserWriter, shipped in 1985, and have twice led international delegations of the TEX Users Group in visits to Adobe Systems to discuss PostScript, PDF, and font issues. In the early 1990s, I was also an invited member of the Adobe Acrobat Council, a group of about a dozen people from industry and academia who advised Adobe, and its President and Chief Executive Officer, on the technical and marketing directions for PDF before PDF was publicly announced; I'm pleased to see that history has proved our advice correct.

2 Test plots

The plots in this document were made with the MAPLE commands

```
plot(sin(x)/sqrt(x), x = 0 .. 100);
plot(sin(x)/sqrt(x), x = 0 .. 100, numpoints = n);
```

where the number of points, n, is recorded in the plot filename. Before saving the plots, in most cases, the font size was reset to 18pt from the too-small default of 10pt. The plots were saved by clicking on the plot in the MAPLE window, then selecting the Export-to-Encapsulated-PostScript menu path.

It is worthwhile to examine the plots under magnification in a PDF viewer to see the serious line-quality issues that appeared in MAPLE 9.0, and remain in the MAPLE 9.5 release that I installed on 10-Dec-2004 on Apple MacOS PowerPC, GNU/Linux IA-32, Microsoft Windows IA-32, and Sun Solaris SPARC systems in the Mathematics and Physics Departments.

3 How historic MAPLE worked

MAPLE 8.0 produces a smooth approximation to the test function, as shown in Figure 1. Although the plots are superficially quite similar, the increased number of points on the right-hand plot makes the maxima and minima smoother than before, and eliminates the sharp edges, as shown in the magnified view in Figure 2.

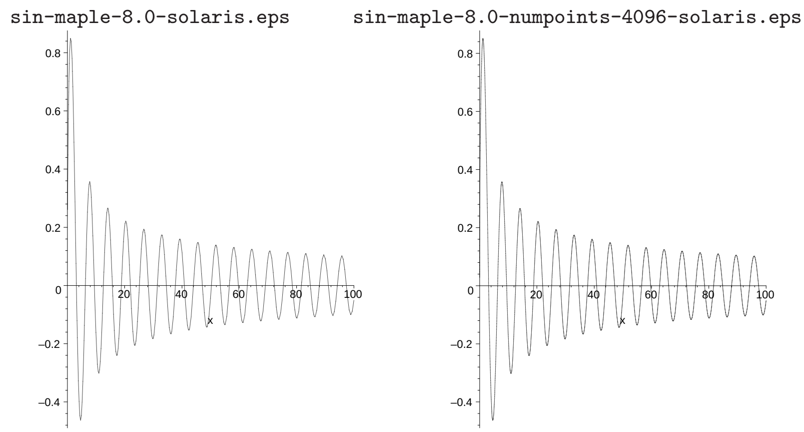


Figure 1: MAPLE 8.0 with default and increased numbers of points.

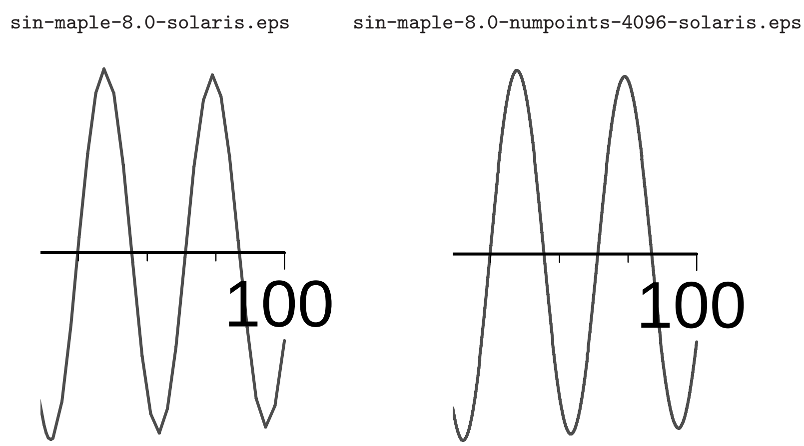


Figure 2: MAPLE 8.0 with default and increased numbers of points under magnification.

Graphical irregularities and red herrings, such as visibly-straight lines appearing where there should be curved lines, are highly undesirable in pedagogy, because students and other novices often do not have the background to recognize and understand that they *are* artifacts, and *why* they are so. Instead, like most of the general public, they are much more likely to assume that because a computer produced the graph, it must be correct.

Part of our teaching must be directed at disabusing them of such false beliefs, and of instilling in them a healthy dose of scepticism, and an ability and indeed, personal obligation, to do critical analyses of published and broadcast material.

4 MAPLE 9 graphics output is a huge step backward

MAPLE 9.0 produces a colored background on Microsoft Windows 2000 that is absent on Apple MacOS and Sun Solaris, the plots from the two operating systems have different sizes, and one has a legend that the other lacks, as shown in Figure 3. This is unexpected and unwanted, because our MAPLE users move frequently from one architecture to another, and identical results across all supported platforms for numerical, symbolic-algebra, and graphical expressions are an absolute necessity.

In mathematics, physics, and computer science, the de facto document preparation system is the combination of the TEX typesetting engine with the LATEX markup system, and the METAFONT font design system. TEX and METAFONT are unusual and significant in many respects; two of them are their designer's commitment to bit-for-bit identical output on all platforms, and their high degree of reliability and portability. They have now been in use for 26 years, from embedded turnkey systems, to desktops, minicomputers, mainframes, and supercomputers. The longevity, openness, and wide availability of TEX and METAFONT have contributed enormously to scientific communication and technical publishing. MAPLE also has a long tradition for many of us, and its reliability is paramount. Also, most of its 300 or so manuals, journal, and books are typeset with TEX (see `http://www.math.utah.edu/pub/tex/bib/index-table-m.html#maple-extract` and `http://www.math.utah.edu/pub/tex/bib/index-table-m.html#maple-tech`).

Notice also that the vertical-axis numbering in the MAPLE 9.0 plots overlaps the axis, and the zero label on the horizontal axis is obscured by the vertical axis. Under magnification, the bottom two ticks on the vertical axes are abnormally spaced. In contrast, the MAPLE 8.0 output shows no overlap of numbers with the axes, the axis ticks are regularly spaced, and the zero label on the horizontal axis is suppressed to avoid being obscured by the vertical axis, as shown in the magnified views in Figure 4.

The varying line thickness in the plots in Figure 3 is highly objectionable, and is the first problem that we spotted when we first installed MAPLE 9.0. It was a major factor in our decision to not make it the default version at the following semester break. We continue to use MAPLE 8.0 as our default, with multiple historical versions available to our user communities, as shown in Figure 5.

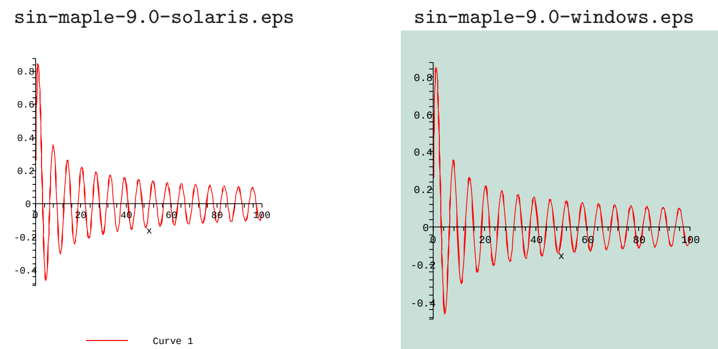


Figure 3: MAPLE 9.0 on Sun Solaris and Microsoft Windows.

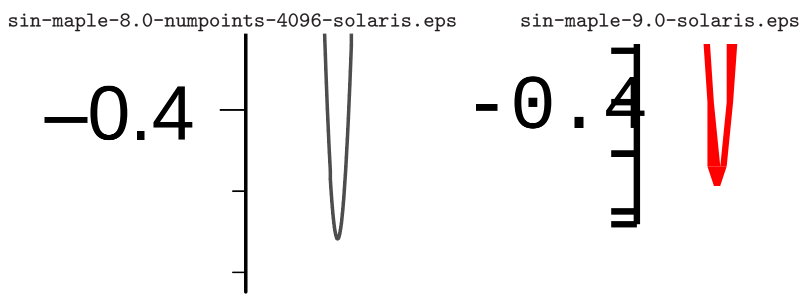


Figure 4: Axis details in MAPLE 8.0 and MAPLE 9.0.

MAPLE 9.5 on Apple MacOS and Sun Solaris produces similar results, except that the numbers no longer overlap the vertical axis: see Figure 6:

Increasing the number of points has the bizarre effect of worsening the approximation to the curve, as shown in Figure 7 and Figure 8.

Further increasing the number of points by a factor of ten shows even worse results, and the Microsoft Windows version shows the same colored background that MAPLE 9.0 has: see Figure 9 and Figure 10.

For comparison, the latest version of MATLAB, 7.0r14, produces the plot shown in Figure 11.

`mapleV2`	`mapleV4`	`mapleV5.1`	`mapleV8`	`mapleV9`
`mapleV3`	`mapleV5`	`mapleV7`	`mapleV8.01`	`mapleV9.5`
`xmapleV2`	`xmapleV4`	`xmapleV5.1`	`xmapleV8`	`xmapleV9`
`xmapleV3`	`xmapleV5`	`xmapleV7`	`xmapleV8.01`	`xmapleV9.5`

Figure 5: Available versions of Maple at the University of Utah Mathematics Department and Physics Department. The programs `maple` and `xmaple` are symbolic links to `mapleV8` and `xmapleV8`, respectively.

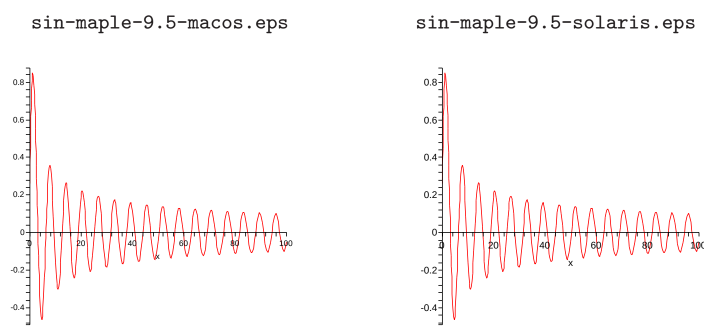


Figure 6: MAPLE 9.5 on Apple MacOS and Sun Solaris.

5 MAPLE 9 outputs nonconformant PostScript

There are other problems in MAPLE 9 as well. A properly-formatted Encapsulated PostScript file should have the comment structure documented in Adobe Technical Note #5001, *PostScript Language Document Structuring Conventions*, and Adobe Technical Note #5002, *Encapsulated PostScript File Format Specifications*, and produced by the `lptops` (line printer to PostScript) filter available at `http://www.math.utah.edu/pub/lptops`, as shown in Figure 12. Here, the separator lines with equals signs are additions that make the logical blocks more visible. The `%%PageTable` line is an extension that is not part of the Adobe specifications.

sin-maple-9.5-numpoints-1000-solaris.eps sin-maple-9.5-numpoints-4096-solaris.eps

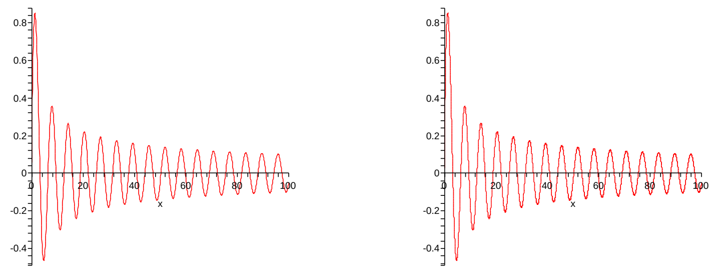


Figure 7: MAPLE 9.5 and the `numpoints` option

sin-maple-9.5-numpoints-1000-solaris.eps sin-maple-9.5-numpoints-4096-solaris.eps

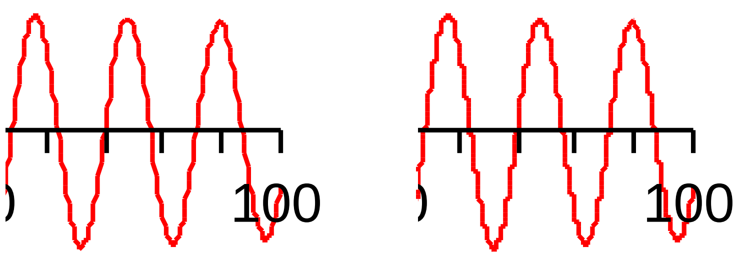


Figure 8: MAPLE 9.5 and the `numpoints` option under magnification.

sin-maple-9.5-numpoints-40960-solaris.eps sin-maple-9.5-windows.eps

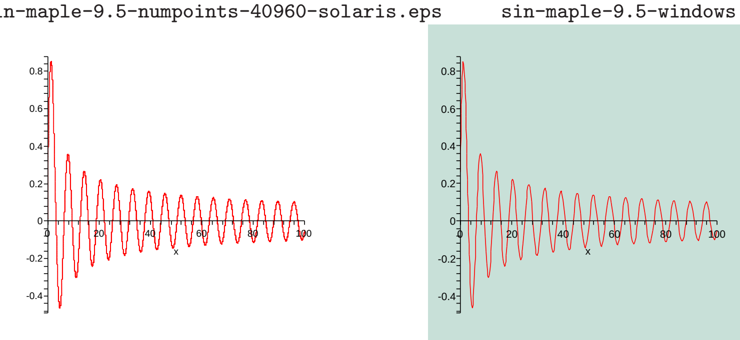


Figure 9: MAPLE 9.5 with a large `numpoints` value on Sun Solaris, and a default plot in Microsoft Windows.

sin-maple-9.5-numpoints-40960-solaris.eps sin-maple-9.5-windows.eps

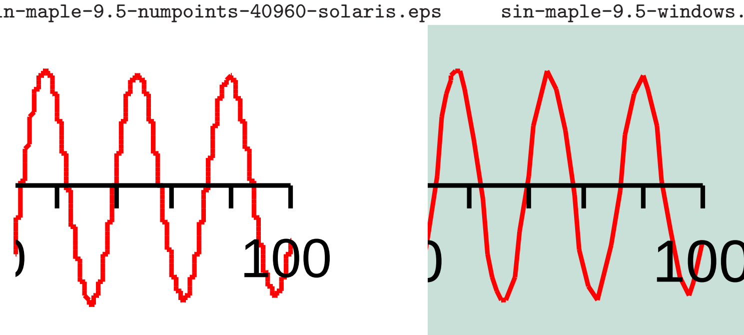
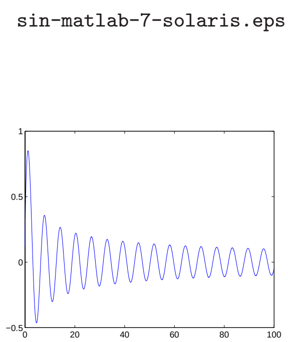


Figure 10: MAPLE 9.5 with a large `numpoints` value on Sun Solaris, and a default plot in Microsoft Windows, under magnification.



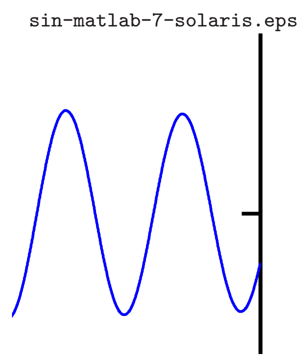


Figure 11: MATLAB 7.0r14 rendering with 6400 equally-spaced points on the left, and a magnified view on the right. The MATLAB program is simple:

```
x = [0:1/64:100]; plot(x, sin(x)./sqrt(x));
```

```
$ echo Hello | lptops -q | grep "^%"
%!PS-Adobe-3.0
%%Title: lptops '-q'
%%CreationDate: Sat Dec 11 05:40:15 2004
%%Creator: lptops [Line Printer to PostScript] version 3.1.7 [02-Jan-2003]
%%+     compiled on Jan 23 2004 16:48:32
%%For: Nelson H. F. Beebe <beebe@psi.math.utah.edu>
%%BoundingBox: 0 0 612 792
%%DocumentMedia: A 612 792 0 () ()
%%DocumentData: Clean7Bit
%%DocumentFonts: font Courier
%%DocumentNeededResources: (atend)
%%DocumentSuppliedResources: (atend)
%%Orientation: Portrait
%%PageOrder: Ascend
%%Pages: (atend)
%%EndComments
%========================================================================
%%BeginProlog
%%EndProlog
%========================================================================
%%BeginSetup
%%EndSetup
%========================================================================
%%Page: 1 1
%%BeginPageSetup
%%EndPageSetup
%%PageTrailer
%========================================================================
%%Trailer
%%DocumentNeededResources: font Courier
%%DocumentSuppliedResources:
%%Pages: 1
%%PageTable:    1 1 -1  2 2 -1
%%EOF
```

Figure 12: Specification-conforming comment structure from `lptops`.

Just before the `%%PageTrailer` comment, there is a PostScript `showpage` operator that causes the display device or printer to copy the raster image to the output medium. Documents that include Encapsulated PostScript files in their PostScript output simply redefine that operator to do nothing, as shown in Figure 13.

```
gsave                   %% save the graphics state
/showpage { } def       %% disable showpage
... included Encapsulated PostScript file goes here ...
grestore                %% restore the graphics state
```

Figure 13: Wrapping an Encapsulated PostScript figure inside another PostScript document.

Figure 14 shows the comment structure produced by MAPLE 9.0 on Sun Solaris. The identical comment structure is produced for MAPLE 9.0 and 9.5, on Apple MacOS, Microsoft Windows, and Sun Solaris. Worse, there is no `showpage` operator.

```
$ grep '^%[%!]' sin-maple-9.0-solaris.eps
%!PS-Adobe-3.0 EPSF-2.0
%%Title: Maple plot
%%Creator: Maple
%%BoundingBox: 0 0 400 400
%%EndComments
```

Figure 14: Faulty MAPLE 9.0 PostScript document structure.

Figure 15 shows the comment structure in MAPLE 8.0 PostScript output. That output properly contains a `showpage` operator near the end.

The MAPLE 8.0 comments are missing several required by Adobe's specifications. They could have, and should have, included a more precise `%%Creator` comment that records the MAPLE version and release date, and the host operating system. However, they do document the fonts used, they provide an accurate bounding box, and the output is formatted to place the lower-left corner away from the lower-left page corner. This is extremely important, since it makes it possible to print the file in isolation without loss of information near the page edges, an area that cannot be imaged because it is used by

```
$ grep '^%[%!][^%]' sin-maple-8.0-solaris.eps
%!PS-Adobe-3.0 EPSF-2.0
%%Title: Maple plot
%%Creator: Maple
%%Pages:  1
%%BoundingBox: 84 136 503 655
%%DocumentNeededResources: font Helvetica
%%EndComments
%%IncludeResource: font Helvetica
%%EOF
```

Figure 15: Marginally acceptable MAPLE 8.0 PostScript document structure.

the printer paper-transport mechanism.

For comparison, Figure 16 shows the comment structure from MATLAB 7.0r14. Its output includes a `showpage` operator immediately before the `%%Trailer` comment, and moves the plot away from the lower-left page corner. The comment appears to conform to Adobe's specifications, matching more closely what `lptops` produces.

For another comparison, using the minimal PostScript file shown in Figure 17, `epsutil` (available at `http://www.math.utah.edu/pub/epsutil`) produces the comment structure shown in Figure 18.

```
$ grep '^%[%!]' sin-matlab-7-solaris.eps
%!PS-Adobe-3.0 EPSF-3.0
%%Creator: MATLAB, The Mathworks, Inc.
%%Title: /home/0077/sy/beebe/sin-solaris-matlab-7.eps
%%CreationDate: 12/10/2004  12:50:24
%%DocumentNeededFonts: Helvetica
%%DocumentProcessColors: Cyan Magenta Yellow Black
%%LanguageLevel: 2
%%Pages: 1
%%BoundingBox:    81   227   529   564
%%EndComments
%%BeginProlog
%%EndProlog
%%BeginSetup
%%EndSetup
%%Page: 1 1
%%BeginPageSetup
%%PageBoundingBox:    81   227   529   564
%%EndPageSetup
%%BeginObject: obj1
%%IncludeResource: font Helvetica
%%EndObject
%%Trailer
%%EOF
```

Figure 16: Specification-conforming comment structure from MATLAB 7.0r14.

```
$ cat hello.eps
%!PS-Adobe
%%BoundingBox: 74 66 258 99
72 72 moveto
/Helvetica findfont 36 scalefont setfont
(Hello, world) show
showpage
```

Figure 17: Minimal PostScript file with a famous greeting.

```
$ epsutil hello.eps | grep '^%[!%]'
%!PS-Adobe-3.0 EPSF-3.0
%%Title: /usr/local/bin/gawk -f epsutil.awk hello.eps
%%CreationDate: Sat Jun 29 06:19:29 1996
%%Creator: epsutil.awk Version 2.03 [23-Feb-2004]
%%For: Nelson H. F. Beebe <beebe@psi.math.utah.edu>
%%BoundingBox: 74 66 258 99
%%DocumentMedia: A 612 792 0 () ()
%%DocumentData: Clean7Bit
%%DocumentFonts:
%%DocumentNeededResources:
%%DocumentSuppliedResources:
%%Orientation: Portrait
%%PageOrder: Ascend
%%Pages: 1
%%EndComments
%%BeginProlog
%%BeginResource: procset idmacros 2.03
%%EndResource
%%EndProlog
%%BeginSetup
%%EndSetup
%%Page: 1 1
%%BeginPageSetup
%%EndPageSetup
%%BeginDocument: hello.eps
%! PS-Adobe
%%BoundingBox: 74 66 258 99
%%EndDocument
%%BeginResource: procset idshow 2.03
%%EndResource
%%PageTrailer
%%Trailer
%%EOF
```

Figure 18: Specification-conforming comment structure from `epsutil`.

6 Recommendations for MAPLE

This document has shown severe problems with the graphics quality and PostScript language conformance in MAPLE 9.0 and 9.5. These are unacceptable in a commercial product, and importantly, should be very simple to remedy. I suspect that one or two days spent studying the two Adobe Technical Notes cited above, and also Appendices G and H of the earlier second edition of the *PostScript Language Reference Manual*, and a half day editing the MAPLE source code that outputs PostScript files, would be sufficient to repair the PostScript comment problems.

I have no idea why the curve quality is so poor, or what would need to be done to repair it. Nevertheless, it *must* be fixed!

There are additional steps that should be taken to improve MAPLE's graphical output:

- The offering of low, medium, and high quality options in MAPLE menus should be removed, since MAPLE should by default *only* produce plots of superb quality. PostScript and PDF are marvelous technologies that make this goal possible. Machines and printers are fast enough today that the small time savings once possible by lowering output quality on dot-matrix and inkjet printers is no longer relevant. It is much more important for the customer image of MAPLE that its graphics be outstanding.

- Document-structuring comments must conform to Adobe's specifications, and the output PostScript must be terminated by a `showpage` operation, so that graphics files can be printed individually.

- The bounding box should place the lower-left corner away from the (0,0) page origin, preferably at (28,28) [1cm offset], (72,72) [1in offset], or (100,100) [100bp offset]. The latter is probably the best choice, being less biased about systems of measurement, and easier to deal with by humans.

- Support for PDF output should be added, for these reasons:
  - MacOS 10 uses PDF as its native graphics format.
  - PostScript level 3 printers can handle PDF directly without conversion back to PostScript.
  - PDF's page-order and font independence, and the availability of free and/or commercial PDF viewers on all common platforms, has made it more widely used on the World Wide Web than PostScript.
  - PDF viewers support text search in documents; few PostScript or DVI viewers do so.

- TeX users can produce PDF directly with pdfTeX, or else convert DVI-to-PostScript driver output to PDF with Adobe `distill`, Ghostscript `ps2pdf`, or Frank Siegert's excellent `pstill` (available at `http://www.wizards.de/~frank/pstill.html`).
- Unlike PostScript, PDF can support transparency, a feature that could be put to excellent use in MAPLE output of line drawings and surfaces in three dimensions.

Because PDF is not programmable, and is rarely editable, it is a *not* a replacement for PostScript for graphical image representation. Both PostScript and PDF output formats are needed.

The PDF text must be carefully formatted to produce high resolution, so that curves remain smooth even under magnification in a PDF screen viewer, and so that it can be printed on high-resolution output devices. This cannot be achieved with the Apple MacOS and Microsoft Windows PDFWriter printer drivers; instead, carefully handcrafted PDF that conforms to Adobe standards must be produced directly by MAPLE.

- It would be worth investigating the fitting of curves to the Bézier curves supported by PostScript. That would likely make the output more compact, and preserve smoothness on even the highest-resolution output devices, and under magnification in interactive PDF screen viewers, because the rasterization would be of a mathematical curve, rather than of a series of connected line segments.
- The MAPLE options that control plot appearance are frankly, eclectic, unpredictable, poorly documented, and hard to use. For example, in my quest to eradicate unwanted straight-line segments in smooth curves, I searched the interactive help facility, turning up a `resolution` option; unfortunately, it appeared to have no effect. Eventually, I searched the *Maple Learning Guide* in the file `lrnguide.pdf` and discovered the `numpoints` option, which appears to receive no mention in the help system. Nevertheless, the need for such an option should be exceedingly rare: MAPLE should automatically choose the number of points in curves so that even under reasonable magnification (say, $10\times$), the curves remain smooth.
- Axis numbering, labeling, and legends require more care. Journal publishers, such as the American Chemical Society, the American Physical Society, the Association for Computing Machinery, and IEEE, generally publish detailed instructions for preparation of line drawings, with minimal line widths and font sizes. Many scientific journals use a compact two-column format, and journal figures are often quite small, perhaps 6cm $\times$ 6cm. MAPLE's default line widths and font sizes are far too small to image well at such figure sizes.

- Portrait mode must be the default orientation for output plots, since that is the direction that humans view the figures in, and since few users have the tools or the PostScript knowledge to rotate figures in landscape orientation back to portrait form. Landscape displays are highly undesirable in electronic documents, since not all PDF and PostScript viewers are capable of page rotation.

- MAPLE's default graphical output in PostScript should be ready for publication in books and journals, and conform to publisher guidelines.

- MAPLE's axis numbering is poor, producing the sequence **0 0.2 0.4 0.6 0.8 1** instead of the conventional **0.0 0.2 0.4 0.6 0.8 1.0**. Not only does the conventional numbering look better and more uniform, it also follows the scientific concept of significant digits.

- Because it is impossible to predict how, and at what size, the PostScript graphics are used in customer documents, it is strongly advisable to produce parametrized PostScript that allows easy editing to alter font names, font sizes, axis label positions, and legend positions, *without* reducing output quality.

  Text, for example, should be displayed using separate macros that show the text left-adjusted, centered, or right-adjusted. These handle the numbering needs for horizontal and vertical axes, and axis and graph titles. There should also be macros that control text string orientation, so that a short label along a vertical axis can be set horizontally for readability, and a long label vertically, parallel to the axis.

- Lines should be classified according to use: main axes, major ticks, minor ticks, graph outline, curves, and so on, with macros that set their separate line widths relative to a base line width, multiplied by a uniform scale factor that can be set in just one place, and tweaked by a simple edit according to user requirements. Similar parametrization is illustrated below for fonts.

- No dimensions of object positions should be hard-coded: instead, they should be given symbolic names that are defined in one easy-to-change place. Users can then easily adjust positions of legends, titles, and so on.

- Fonts and font sizes should be declared in one place inside user-adjustable macros, as shown in Figure 19. `epsutil`, `lptops`, and `psposter` (available at `http://www.math.utah.edu/pub/psposter`) all make extensive use of this technique. Those macros should be well documented in the comments, so that the figures can be subsequently edited far from their origin, on a system where MAPLE is not available.

- When curves are represented by points, there are potentially a lot of coordinates needed to specify PostScript paths. Figure 20 shows a fragment from the MAPLE 9.5 plot file, `sin-maple-9.5-solaris.eps`.

```
/DefaultFont Helvetica   def
/AxisFont    DefaultFont def
/LabelFont   DefaultFont def
/LegendFont  DefaultFont def
/TitleFont   DefaultFont def

/DefaultFontSize 18 def
/FontScale        1 def
/AxisFontSize    { DefaultFontSize FontScale mul }         def
/LabelFontSize   { 1.0 DefaultFontSize mul FontScale mul } def
/LegendFontSize  { 0.75 DefaultFontSize FontScale mul }    def
/TitleFontSize   { 1.2 DefaultFontSize mul FontScale mul } def
```

Figure 19: Font parametrization in PostScript.

```
%drawLine 40 180 35 180
40 -180 moveto 35 -180 lineto stroke
0 0 0 setrgbcolor
%drawLine 78 245 78 250
78 -245 moveto 78 -250 lineto stroke
0 0 0 setrgbcolor
%drawLine 40 76 35 76
40 -76 moveto 35 -76 lineto stroke
0 0 0 setrgbcolor
%drawLine 40 255 35 255
40 -255 moveto 35 -255 lineto stroke
0 0 0 setrgbcolor
```

Figure 20: Verbose PostScript from MAPLE 9.5.

The PostScript operators `lineto`, `moveto`, and `lineto` each occur more than 400 times, and could be more compactly represented by single-letter abbreviations. The absolute coordinates could be replaced by relative coordinates to shorten digit counts. The 400 or so `setrgbcolor` operators are almost entirely redundant: once color is set in a PostScript graphics context, it remains set.

By contrast, Figure 21 shows a PostScript fragment from the MATLAB plot, showing the use of multipoint paths and relative coordinates to reduce output volume, speed PostScript rasterization, and improve the appearance of line-segment joins.

```
1 19 0 20 1 20 1 19 0 20 1 19 0 20 1 19
1 19 0 19 1 19 0 18 1 19 1 18 0 19 1 18
...
1 -38 0 -39 1 -41 1 -44 0 -46 1 -50 0 -53 1 -58
1 -64 0 -74 1 -87 0 -113 700 2219 157 MP stroke
```

Figure 21: Compact PostScript from MATLAB 7.0r14.

One can go even further in compacting PostScript without using its binary compression forms, which are undesirable for graphics files, because they can make hand editing impossible. The TeX DVI drivers `dvips` (written by Tom Rokicki) and `dvialw` (written by me) use a large number of single-character commands to handle the common cases of short relative movements, which occur between words and characters in typeset text, but are also common in continuous curves. Figure 22 shows a sample of each, using the famous `story.tex` file from the first example in *The TeXbook*, reproduced as the typeset document shown in Figure 23, but using the fonts of this document, rather than its original ones.

- Maple needs to be available on more platforms, including at least GNU/Linux on AMD64, EM64T, and IA-64, Solaris for IA-32 and AMD64, and possibly also for the various BSD Unix systems (BSD/OS, FreeBSD, NetBSD, and OpenBSD) on at least IA-32. We currently have all but two of these systems, and the 64-bit systems offer both the large memory needed for symbolic computation, and the high performance that is sometimes required. We have on occasion had MAPLE jobs that ran for many days.

  In the past, supporting software on multiple platforms meant significant extra costs of packaging and warehousing. Today, most software can, and should, be written to compile, validate, and install seamlessly across all Unix, Gnu, and POSIX systems. The World Wide Web makes it unnecessary to prepare physical shrink-wrapped packages for the platforms with a smaller market: instead, all that is needed for MAPLE is a base distribution of the platform-independent part (by far the largest part of the distribution anyway), plus a single archive of each of the `bin.ARCHNAME` directories. These could be made available to licensed customers over the Internet, without ever needing to be burned onto a CD or DVD, packaged, and shipped.

```
dvialw:
    %%Page: 1 1
    %%BeginPageSetup
    %%PageBoundingBox: 0 0 612 792
    %%HiResPageBoundingBox: 0.000000 0.000000 612.000000 792.000000
    DVIALWdict begin
    %%EndPageSetup
    BOP
    F1 2228 5476 A(A)g(SHOR)17 X(T)f(ST)t(OR)e(Y)d F2 74 183 J(b)g(y)e(A.)
    19 X(U.)s(Thor)t F3 1063 183 C(Once)g(upon)23 X(a)t(time)t(,)f(in)u(a)t
    (distant)t(galaxy)t(called)t 1696 18 L(\250)g 15 18 C(O)g 70 1 L(\250)g
    7 1 C(oc)g(\270)-37 X(,)k(ther)24 X(e)e(lived)s(a)s(computer)t 1868 100
    C(named)g(R.)19 X(J.)s(D)t(rofnats)f(.)e 124 100 J(Mr)g(.)b(D)19 X
    (rofnats\227or)f(\223)t(R.)e(J.,)t(\224)c(as)t(he)t(pr)t(eferr)e(ed)e
    (to)t(be)t(called\227)t(was)t(happiest)t(when)t 124 100 C(he)g(was)19 X
    (at)s(work)t(typesetting)t(beautiful)s(documents)t(.)e
    EOP
    end
    %%PageTrailer

dvips:
    %%Page: 1 1
    1 0 bop 1628 523 a Fc(A)18 b(SHOR)n(T)e(ST)n(OR)m(Y)1702
    706 y Fb(b)n(y)i(A.)g(U.)h(Thor)639 888 y Fa(Once)k(upon)i(a)e(time)n
    (,)h(in)f(a)h(distant)f(galaxy)h(called)2337 870 y(\250)2322
    888 y(O)2392 887 y(\250)2385 888 y(oc)-37 b(\270)t(,)24
    b(ther)n(e)f(lived)f(a)i(computer)515 988 y(named)18
    b(R.)h(J.)g(D)o(rofnats)n(.)639 1088 y(Mr)-5 b(.)20 b(D)o
    (rofnats\227or)f(\223)n(R.)h(J.,)l(\224)f(as)g(he)g(pr)n(eferr)n(ed)i
    (to)d(be)g(called\227)h(was)h(happiest)g(when)515 1187
    y(he)e(was)i(at)e(work)g(typesetting)g(beautiful)h(documents)n(.)p
    eop
    %%Trailer
```

Figure 22: Compact PostScript for typeset text, produced by two TeX DVI drivers.

A SHORT STORY

by A. U. Thor

Once upon a time, in a distant galaxy called Ööç, there lived a computer named R. J. Drofnats.

Mr. Drofnats—or "R. J.," as he preferred to be called— was happiest when he was at work typesetting beautiful documents.

Figure 23: A typeset document from *The TeXbook*.