Plots in \LaTeX: Gnuplot, Octave, make

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1. **Goals**

This is the Unix philosophy: Write programs that do one thing and do it well. Write programs to work together. Write programs to handle text streams, because that is a universal interface.

*Doug McIlroy*

1. We do not want to held computer’s arm. Computer should know what to do and when!

2. Harmony between the text and the plots. Same fonts, same style.

3. We want $\TeX$ labels on the plots.

4. We want to use external programs well designed to handle graphics.
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2. Makefiles

Final document
2. Makefiles

Final document

\LaTeX \text{ file}
2. Makefiles

Final document

\texttt{\LaTeX} file Figure
2. Makefiles

Final document

\text{T}_{\text{EX}}\text{ file} \quad \text{Figure}

Program
2. Makefiles

- Final document
  - \( \text{T}_{\text{E}}\text{X} \) file
  - Figure
    - Program
    - Data
2. Makefiles

Dependencies:

1. If \( \text{T\AE}X \) file or figure change, we want to recompile the document.

2. If data or program change, we want to recompile the figure.
2. Makefiles

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2. If data or program change, we want to recompile the figure.
Makefile & dependencies:

document.pdf: document.tex

document.pdf: figure-fig.tex

figure-fig.tex: data.dat

figure-fig.tex: figure.gp
A more complex case:

![Diagram](https://via.placeholder.com/150)

Final document

Figure 1

TEX file

Figure 2

Data 1

Program 1

Data 2

Program 2
A more complex case:

Final document

Figure 1

Data 1

Program 1

TEX file

Data 2

Program 2

Figure 2

document.pdf: document.tex figure1-fig.tex figure2-fig.tex

figure1-fig.tex: data1.dat figure1.gp

figure2-fig.tex: data1.dat data2.dat figure2.gp
Rules. How to make a PDF?
Rules. How to make a PDF?

%.pdf:   %.tex
          pdflatex $*$
          pdflatex $*$
          pdflatex $*$
Rules. How to make a PDF?

%.pdf: %.tex
   pdflatex $*$
   pdflatex $*$
   pdflatex $*$

A smarter rule:

%.pdf: %.tex
   pdflatex $*$
   while ( grep -q \n      '^-LaTeX Warning: Label(s) may have changed' $*.log ) ; \n      do pdflatex $*; \n   done
   pdflatex $*$
3. \texttt{\TeX}-compatible Graphics

1. A graphics program should generate a \TeX\ file for textual material. . .

2. And a graphics file (EPS or PDF) to be included.
3. **\(\text{T\e X}\)-compatible Graphics**

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3. **\TeX**-compatible Graphics

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3. \texttt{\LaTeX}-compatible Graphics

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2. And a graphics file (EPS or PDF) to be included.

In main \LaTeX\ file:

\begin{verbatim}
\input{figure-fg}
\end{verbatim}
3. \textbf{\LaTeX}-compatible Graphics

1. A graphics program should generate a \LaTeX\ file for textual material...

2. And a graphics file (EPS or PDF) to be included.

In main \LaTeX\ file:

```
\input{figure-fig}
```

In Makefile

document.pdf: figure1-fig.tex figure2-fig.tex ...

```
%-fig.tex: DEPENDENCIES
    RULES
```
4. Gnuplot

Skeleton Program:

```plaintext
set terminal epslatex
set output "FILE-fig.tex"
COMMANDS
set output
```
4. Gnuplot

Skeleton Program:

set terminal epslatex
set output "FILE-fig.tex"

COMMANDS
set output

Makefile:

%-fig.tex: %.gp
   gnuplot $<
Example:

\[ f(x) = \exp \left( -|x|^2 \right) \]
set terminal epslatex color
set output "function-fig.tex"
set pm3d               # Colored surface
unset surface         # We do not want to plot the mesh lines
set isosamples 100, 100  # Smooth surface
set ztics 0.2          # Increment for z tick marks
set cbtics 0.2         # Increment for colored box
set xrange [-1.5:1.5]  
set yrange [-1.5:1.5]  
set label 1 \  
'\$f(\mathbf{x})=\exp\left(-\|\mathbf{x}\|^2\right)$' \  
  at -1.5,-1,1.2  
set label 2 \  
'\$\textstyle\max_{\mathbf{x}\in \mathbb{R}^2} f(\mathbf{x})$' \  
  at 1,1,1.3  
set arrow 1 from 1,1,1.3 to 0,0,1 front
splot exp(-x**2-y**2) title ""  
set output
Another example:

Stopping distance, feet

$$y = 0.48 \cdot x^{1.6}$$

Speed, mph
set terminal epslatex color
set output "cars-fig.tex"
set logscale xy
set xrange [1:100]
set yrange [1:500]
set xlab 'Speed, mph'
set ylab 'Stopping distance, feet'
set label 1 \ 
  \rotatebox{41}{$y=0.48\cdot x^{1.6}$} \ 
  at 1.4, 3
plot "cars.dat" with points pointtype 4 title "", \ 
  exp(-0.73+1.6*\log(x)) \ 
  linecolor 2 linewidth 5 title ""
set output
5. Octave

Skeleton program:

```octave
figure('visible','off');
COMMANDS
print -depslatex "-SX,Y" "figure-fig.tex"
```
5. Octave

Skeleton program:

```matlab
figure('visible','off');
COMMANDS
print -depslatex "-SX,Y" "figure-fig.tex"
```

Makefile:

```
%-fig.tex: %.m
   octave $<
```
Example:
```matlab
figure('visible','off');
ber1 = @(x) -real(besselj(1,x*exp(pi*1i/4)));
bei1 = @(x) imag(besselj(1,x*exp(1i*pi/4)));
delta = @(x) ber1(x)-bei1(x);
rho0 = fsolve(delta,4);
x=0:0.1:4;
plot(x,delta(x),'linewidth',2);
hold on;
plot([rho0], [0], 'o', 'linewidth', 10);
text(rho0, 0.15, '\colorbox{white}{$\rho_0$}', 'horizontalalignment', 'center');
text(rho0, -0.2, sprintf("\colorbox{white}{$\rho_0$}", rho0), 'horizontalalignment', 'center');
title (''); legend ('off'); grid();
xlabel ('$\rho$');
ylabel ('$\ber_1\rho-\bei_1\rho$');
print -depslatex '-S600,400' "kelvin-fig.tex"
```
Why this file would cause \TeX errors?
Two macros: \texttt{\bei} and \texttt{\ber}. Need to define them (amsmath):

\verb|\DeclareMathOperator{\ber}{ber}|  
\verb|\DeclareMathOperator{\bei}{bei}|
Two macros: \bei and \ber. Need to define them (amsmath):

`\DeclareMathOperator{\ber}{ber}`
`\DeclareMathOperator{\bei}{bei}`

Our generated TeX file uses fonts and macros from the main one!
6. Questions and Answers

**Question:** Gnuplot and Octave use EPS, but we use `pdflatex`. How does it work?

**Answer:** Modern \TeX translates EPS graphics to PDF on the fly—and uses timestamps like `make`!
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Question: It is too boring to write all these dependencies:
\begin{verbatim}
document.pdf: figure1-fig.tex figure2-fig.tex ...
\end{verbatim}
Can computer do this for us?

Answer: Just use a script \texttt{makefigdepend.pl} and add to Makefile
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document.pdf: figure1-fig.tex figure2-fig.tex ... Can computer do this for us?

**Answer:** Just use a script `makefigdepend.pl` and add to Makefile

```
depend:  ${TEXFILES}
       perl makefigdepend.pl \
       ${TEXFILES} > depend
```

-include depend
**Question:** What about cleaning the intermediate files?

**Answer:** Use `clean` goal:
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```plaintext
clean:
  $(RM) *.aux *.bbl *.dvi *.log *.nav *.snm \
  *.out *.toc *.blg *.lof *.lot \
  *.eps *-pics.* *-fig* depend

distclean: clean
  $(RM) ${PDFS}
```
7. Conclusions

1. You can make a good scientific & engineering graphics with tools like Gnuplot and Octave

2. You can automate boring parts of your work with Makefiles
7. Conclusions

1. You can make a good scientific & engineering graphics with tools like Gnuplot and Octave

2. You can automate boring parts of your work with Makefiles

Machines should work. People should think
An old IBM phrase
A. Makefile for This Talk

TEXFILES = \
  gnuplotmk.tex

PDFS = ${TEXFILES:.tex=.pdf}

all: ${PDFS}

%.pdf: %.tex
  (RM) *.toc
  pdflatex *
  - bibtex *
  (RM) *.toc
  pdflatex *
  - while ( grep -q '^LaTeX Warning: Label(s) may have changed' *.log ); do pdflatex *; done
  pdflatex *

%-fig.tex: %.gp
  gnuplot <$
%-fig.tex: %.m
  octave <$

figure-fig.tex:
  touch @$

cars-fig.tex: cars.dat

clean:
  $(RM) *.aux *.bbl *.dvi *.log *.nav *.snm \ 
  *.out *.toc *.blg *.lof *.lot \ 
  *.eps --pics.* --fig* depend

distclean: clean
  $(RM) ${PDFS}

depend: ${TEXFILES}
  perl makefigdepend.pl \ 
  ${TEXFILES} > depend

-include depend
B. Makefigdepend Script

#!/usr/bin/perl

# Extract information from input statements in TeX file

# Usage:
# makefigdepend FILE FILE FILE ... > depend
#

foreach my $file (@ARGV) {
    open FILE, $file;
    $file =~ s/\.tex$/.pdf/;
    while (<FILE>) {
        while (/
            \input(?:\[\^[\]]+\])\*(\[\^[\]]+\])/g) {
            print "$file: $1.tex\n"
        }
    }
    close FILE;
}
exit 0;