Template for Technical Reports

Matthias K. Gobbert

Department of Mathematics and Statistics, University of Maryland, Baltimore County

gobbert@umbc.edu, `www.math.umbc.edu/~gobbert`

Abstract

The abstract should be a succinct summary of your topic and your solution. It should characterize what this report contains including the relevant conclusion from the results presented. Since abstracts are often entered in searchable databases, use only English words, no formulas, no citations, no references to any formula in your text, etc. Its length is often restricted, e.g., to 100 or 200 words.

Key words. Provide five key words or phrases that describe your topic, methods, and results.

AMS subject classifications (2010). Provide up to five subject classification codes here; search for the string "MSC" at `www.ams.org`.

1 Introduction

1.1 Some Technicalities

Where to find this document? You may very well wonder about this point, if this document was given to you in paper form; if you downloaded it from my homepage, this will be obvious, of course. This document is available in the LaTeX area of my homepage, which I will refer to as [1] in the following. You will need to download several files, namely `template.tex`, `template.bib`, the three figures `figconvrateloglog.jpg`, `figconvrateplot.jpg`, and `mesh_solution.jpg`, and the Matlab code `plot_loglog.m`.

How to read this document? Reading the resulting printout is useful, but you must also study carefully the LaTeX-source code; I am trying to use all sorts of examples of sophisticated features. Notice how the result has a very simple appearance about it, but it takes some correct use of LaTeX to achieve this goal at times. When reading the source code, pay particular attention, how all the referencing is done using the commands `\label` to set the label and `\ref` to refer to it. There are no separate labels or references for figures, tables, equations, sections, rather the meaning of the `\label` command is determined from the context, in which it appears. I have adopted the scheme to use the first three letters of the key for each label to indicate to myself, what kind of an object it refers to, so I use 'fig' for figure labels, 'tab' for table labels, etc.; see the source code.

1.2 Philosophy of this Document

This file is designed to show by example, how some relevant features of LaTeX can be used to put together a technical report or a manuscript in such a form that it can be submitted to a journal. Any journal will have to work through your submission anyway, so it makes no sense to try to deal with some of the more technical requirements they have. Rather, your goal should be to provide clean LaTeX, so that the copy editor only has to work on the formalities, but not the contents of the paper. In this spirit, it is very important that you provide information in expected places in some expected format; then the work of any editor is made easy. To this end, I am also trying to use clean but basic LaTeX2$_\varepsilon$; this means that I am trying not to use any fancy features like redefining section headings, etc., but I allow myself the use of popular extensions that are available in packages that come with the standard distribution of LaTeX under Linux. Again, if a journal wants the paper to look different, they will take care of that by using their macros.

The additional purpose of this document is to demonstrate some of those more advanced of features of LaTeX that are typically needed like importing figures or creating reference lists. For more basic commands, please see my basic sample document *Some LaTeX Introduction* [1]; here and throughout, pay attention to my citations, as they are meant to show examples of how to cite certain types of publications. For more information about LaTeX, you should consider [7,8,12]. Leslie Lamport is the original creator of LaTeX, and his book [12] should be the starting point, in particular its Chapters 1 through 3 [12, Chapters 1–3]. The other books [7, 8] are only needed for advanced uses of LaTeX. Both books have similar content overall, but they have different approaches: [7] is 'horizontal' and discusses material organized by package; I suggest to use it, if you want to dig into the innards of LaTeX like redefining section headers or advanced float placement. Compared to that, [8] is organized 'vertically,' because it discusses tools for one topic from all available sources together. If you need to typeset very complicted formulas or have other problems with the mathematics, I recommend [8] because of its well-chosen examples and its organization.

For an excellent discussion of writing mathematics in general, let me point to [9]. It contains more than the title lets on, namely also very relevant remarks on the politics of publishing in mathematics. If you are a Ph.D. student, you should definitely read this book.

2 Importing of Figures

Notice carefully the use of LaTeX's powerful capabilities for automatic cross-referencing demonstrated for equations, tables, and figures in the following subsection, Subsection 2.1.

2.1 Example

We know that the error of the finite difference approximation using centered differences for an elliptic partial differential equation satisfies

$$\|u - u_h\|_\infty = Ch^2 \quad \text{as } h \to 0, \tag{2.1}$$

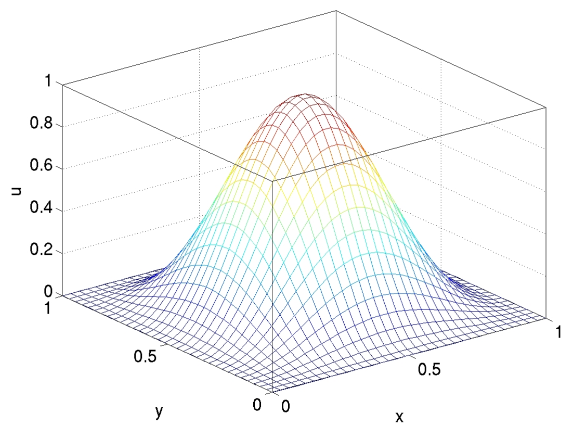


Figure 2.1: Solution to test problem with $h = 1/32$.

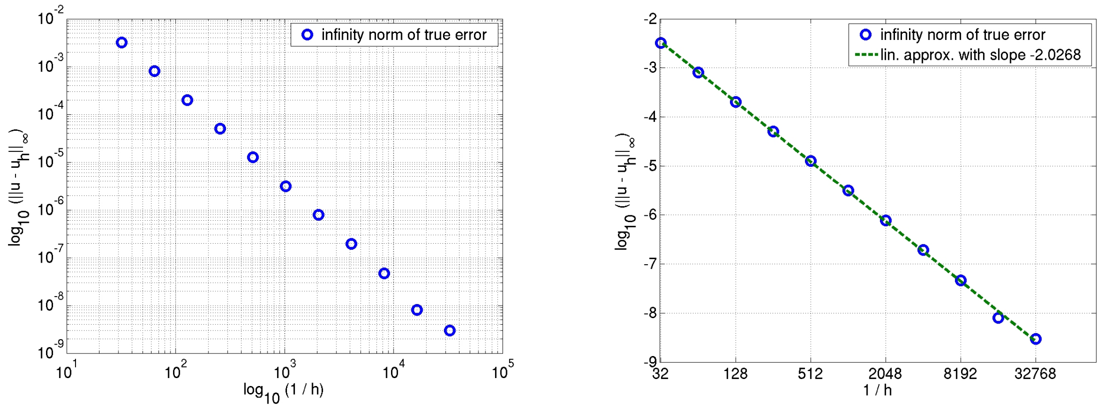
$1/h$	h	$\|u - u_h\|_\infty$	$\frac{\|u-u_{2h}\|_\infty}{\|u-u_h\|_\infty}$	$\frac{\|u-u_h\|_\infty}{h^2}$
32	3.1250e-02	3.2189e-03	N/A	3.2962
64	1.5625e-02	8.0356e-04	4.0058	3.2914
128	7.8125e-03	2.0081e-04	4.0016	3.2901
256	3.9062e-03	5.0191e-05	4.0009	3.2893
512	1.9531e-03	1.2543e-05	4.0015	3.2881
1024	9.7656e-04	3.1327e-06	4.0039	3.2849
2048	4.8828e-04	7.8097e-07	4.0113	3.2756
4096	2.4414e-04	1.9356e-07	4.0348	3.2474
8192	1.2207e-04	4.6817e-08	4.1344	3.1418
16384	6.1035e-05	8.0469e-09	5.8180	2.1601
32768	3.0518e-05	2.9562e-09	2.7220	3.1742

Table 2.1: Demonstration of quadratic convergence rate for the test problem.

where h denotes the maximum mesh spacing and C denotes a constant independent of h. This can be demonstrated numerically by solving a problem with a known solution u like the test problem in [14]. First of all, Figure 2.1 shows the solution of the test problem obtained with a mesh size of $h = 1/32$. The convergence rate is displayed in table form as in Table 2.1. We see that the error decreases by a factor of 4 for each halving of the mesh size. Moreover, it is shown that $\|u - u_h\|_\infty$ divided by h^2 tends to a constant value, which is C in (2.1).

The same can be demonstrated in graphical form. It is conventional to present the result in the form of a log-log plot. Figure 2.2 (a) shows this using Matlab's `loglog` function on the values of $1/h$ and $\|u - u_h\|_\infty$. What are we looking for? The answer is the slope of the almost linear curve, and here is why: If we take the logarithm on both sides of (2.1), we obtain

$$\log_{10}\left(\|u - u_h\|_\infty\right) = \log_{10}\left(Ch^2\right) = \log_{10}\left(C\right) + \log_{10}\left(h^2\right).$$



(a) (b)

Figure 2.2: Plot of true error of finite difference approximation, (a) using log-log plot, (b) using plot of the logarithm of the data; a linear approximation to demonstrate is included to show the linearity given in (2.2).

Using more rules for logarithms, this can be written as

$$\log_{10}\left(\|u - u_h\|_\infty\right) = -2\,\log_{10}\left(\tfrac{1}{h}\right) + \log_{10}\left(C\right), \tag{2.2}$$

which demonstrates that $\log_{10}(\|u - u_h\|_\infty)$ is a linear function of $\log_{10}(1/h)$ with a slope of -2. This is clearly demonstrated in Figure 2.2 (b), which also shows a linear approximation to the data as a dashed line.

2.2 Some Comments

This subsection is here mainly to demonstrate the use of a subsection. This is likely appropriate in your section on Results, because you should try to split those up into more manageable parts.

See the LaTeX-code of this file for the code used to import the figures; the Matlab code used to produce them is included as Appendix A. You will likely not have any space in your report to include actual code, but I wanted to demonstrate the use of an appendix, and that was a good purpose; you also may be able to learn some Matlab from it, if you wish to.

Basically, the importing of postscript files is done using the `\includegraphics` command from the `graphicx` package; this package is loaded at the beginning of this file by the `\usepackage{graphicx}` command. It is not strictly part of LaTeX2$_\varepsilon$, however, the `graphicx` package *is* part of the "standard distribution of LaTeX2$_\varepsilon$," so it is okay (i.e., portable) to use it. (By the way, this "standard distribution" is included with any installation of Linux.)

Now, concretely, the `\includegraphics` command accepts the name of the file to be imported as required argument (in the curly braces). It probably has a default for the size of the imported figure, but you should really control this yourself manually. That can be done by using the `height=` or `width=` flags in the optional argument (in the brackets); you should only give one of them, so that the figure gets scaled proportionally in both directions, that is, without changing its aspect ratio. Here is how Figure 2.1 was coded:

```
\begin{figure} \centering
  \includegraphics[width=0.5\textwidth]{mesh_solution}
  \caption{Solution to test problem with $h = 1 / 32$.}
  \label{figsolplot}
\end{figure}
```

It is best to express your width relative to the `\textwidth` length. If you have multiple figures whose width should all be the same, you can define a length; see the LaTeX-code for the use of `\fwtwo` in Figure 2.2. The `caption` creates the caption, and the `label` sets the label that I am referring to here; please read the source code of this file. You will notice that I am referring to the file `mesh_solution.jpg` without giving its extension `jpg`. That is possible because of the `\DeclareGraphicsExtensions{.jpg}` command immediately after the `\begin{document}` command. If you wish to overwrite its effect, you can always do this by supplying a full file name to the `\includegraphics` command.

A final word on placement of figures and tables: Remember that they are floats, a technical term for a text object that is floated about to fit it in a visually pleasing way as opposed to putting it right in order of the text. The placement of them is perennially a problem, in particular if you have many of them. The best suggestion I have is to resize them reasonably small so that several can fit on one page. That gives LaTeX the most flexibility in placing them. To be complete, placement of floats is controlled by a number of proportional variables like the fraction of a page that can be a float, the fraction of space at top that can be occupied by one, the fraction of space at the bottom that can, etc. If you want to learn about that, I recommend [7], but a general introduction is contained in [12].

3 References

For anyone serious about writing more than a single document, I urge the use of the BibTeX bibliography system. Its complete reference can be found in [12, Appendix B]. In fact, even for a single document, it makes already sense to use it. Let me explain both points presently.

BibTeX is really a bibliography database system. Your whole bibliography is contained in one or several files, in this case the file `template.bib`. In your text, you use then the `\cite` command on the keys of those references. The point is that only those references that you actually use get included in the references (note that for instance the reference `Gobbertiwce` appears in the `bib`-file but not in the bibliography). To accomplish this, you must run LaTeX once to put all requested references in the `template.aux`, then run BibTeX once to pick up the bibliographical information and create the file `template.bbl`, which contains the formated bibliography. Finally, you must run LaTeX *twice*: At first, it includes the bibliography in your document, but during this first pass, it cannot have set the reference labels, so in the second pass, the labels are correctly set. The upshot is, always run LaTeX twice to get all cross-referencing right. Remember that this is needed whenever *any* label or reference changes. In summary, you should issue these commands:

```
pdflatex template
bibtex template
pdflatex template
pdflatex template
```

Notice how `plflatex` is run *twice* to get the cross-references right. That is misleading, though, because you actually need to run it *three* times in total for this document (which is done implicitly in the list above!), if you want to get the formula reference right that appears in the caption of Figure 2.2.

All this is started by the `\bibliography{template}` command at the far end of this file; here, `template` refers to the file `template.bib`. Now, this is really a little unrealistic, because the main advantage of BibTeX is that you can use one `bib`-file for all your research (or one per research project) and maintain them at a central location. So, it is just done this way here, so that you can download one simple file instead of my whole bibliography database. Really, the following is my usual full command:

```
\bibliography{/home/gobbert/soft/tex/biblio/curr/mgenmath,%
              /home/gobbert/soft/tex/biblio/curr/mreschem,%
              /home/gobbert/soft/tex/biblio/curr/mresmath,%
              /home/gobbert/soft/tex/biblio/curr/mresboltz}
```

Actually, even this one is shortened to include only those `bib`-files related to that particular paper; I have more such files with bibliographical information on other research projects.

What are the advantages of using BibTeX? I personally find it actually easier to enter the information, hence I would even use it for a single document. When entering it, I do not have to worry about the referencing style required by the particular journal. Rather, BibTeX worries about that, when writing the `bbl`-file. This appearance is controlled by the `\bibliographystyle{siam}` command, where I have chosen the referencing style for SIAM journals, which is one of the standard ones supplied. So, here is the second advantage: You can change the appearance of your bibliography merely by changing the argument of the `\bibliographystyle` command. You may want to try some other default ones like `plain` (which is pretty plain but elegant) or `ieeetr` (which is quite nice). Many journals supply their own bibliography style files, such as `nature` or `science`, which you might need to download, since they are not part of the standard distribution of LaTeX.

Notice finally that the data in `bib`-file(s) should be sensibly arranged, for instance, alphabetically by the last name of the first author; this order does not impact the order of appearance in your document. A note on order might be in order: In engineering, you often quote references by order of appearance, as you will see when using `ieeetr`. In mathematics, it is conventional to alphabetize references by the last names of all authors, as is done by `siam`. Notice, how [3] appears before [6] independent of chronology, but rather based on the last name of the second author. (In fact, the order of the joint papers with Andreas Prohl is based on alphabetizing the titles, which is quite non-sensical; if I did this by hand, I would choose a chronological order.)

Other technical things include that several references together should be referred to in one `\cite` command, namely as [7, 8, 12] and not as three citations [7], [8], and [12]. Notice also that it does not matter if I say [7,8,12], [7,8,12], or [7,8,12], etc.; see the source code to understand the difference between these three citations! That is accomplished by using the package `cite`. Notice that `cite` does some quite amazing things: For instance, here are all publications cited in this template that involve actual science (as opposed to LaTeX and the like) [2–6, 10, 11, 14, 15]; notice how `cite` groups the references without my doing anything special; see the source code.

You might have noticed that the bibliography style `siam` uses all lowercase letters for the titles of articles. That is not appropriate for proper names of software, places, or natural persons that include Capital letters. In such cases, you must inform BibTeX of these situations by putting braces around either the letter or the word in question; see [4] for an example. It is also possible in the `bib`-file to give LaTeX commands like `\-` to inform it of places for allowable hyphenation in a word that it could not find by itself. That was done for the publisher of [8].

I wanted to provide examples for the most common citations here. So, for instance, [4] is the citation of a paper that has been *submitted* for publication. After acceptance, I would list it as *accepted* like [5]. Finally, after I have received the page proofs, I would list the paper as being *in press* like [2]. (By the way, these papers are used as dummies here; they will remain listed as submitted, accpeted, and in press in this template, even once they appear.) On the other hand, [3] has appeared and shows all relevant information for a journal article. For a book that appeared in a series, [11] would be an example (notice that this one does not have a volume number in that series). [15] is the example of a M.S. thesis completed at UMBC, and [14] is a technical report.

Finally, let me discuss one kind of reference that causes regular confusion on how to use correctly, namely the "private" or "personal communications." [10] is an example of how I have used this category in the past myself; the point was that we used chemical formulas that were only available to us as copy of transparencies. A more typical application would be, if you have an e-mail exchange with a famous and distant researcher as I am characterizing in [13]. I hope this helps to clear up some confusion on the issue. If in doubt, ask your advisor for advice.

4 Conclusions

Finally, let me say that this document was put together with quite a bit of thought over some time, but I probably still forgot a number of very important features that you will need. In doubt, read the original documentation [12], in particular its Chapters 1 through 3.

Acknowledgments

This section is not numbered, because it is an optional add-on to the paper and not directly related to its contents. Acknowledgments for two kinds of support are customary here, namely financial and scientific support: You would list the support of a funding agency or grant here including the grant number. And you can thank others for useful discussion or

kind support or something similar. For instance, you will be the only author of your project report (contrary to a joint paper), but your advisor or someone else may provide substantial support to the completion of this work; you should acknowledge that person here. On the other hand, if I as instructor provide mainly technical and organizational support, that does not warrant a mention here. Notice that if you are funded by a grant, you should ask the PI to suggest an offical phraseology of the acknowledgment.

A Code for Convergence Rate Plots

Here is an example of an appendix and of how to do it in LaTeX. The command `\appendix` is the key, because it switches the counting to Capital letters instead of numbers. Then, continue to use `\section` and `\subsection` as usually.

```
vn0 = 2.^[5 : 15];
venorminf = [  3.2189e-3 ...
               8.0356e-4 ...
               2.0081e-4 ...
               5.0191e-5 ...
               1.2543e-5 ...
               3.1327e-6 ...
               7.8097e-7 ...
               1.9356e-7 ...
               4.6817e-8 ...
               8.0469e-9 ...
               2.9562e-9];

% ... produce standard log-log plot using Matlab's loglog command:
xdata = vn0;
ydata = venorminf;
figure('DefaultAxesFontSize', 20);
H = loglog(xdata, ydata, 'o');
set(H, 'LineWidth',3, 'MarkerSize',10);
grid on;
legend(H, 'infinity norm of true error');
xlabel('log_{10} (1 / h)');
ylabel('log_{10} (||u - u_h||_\infty)');
print -djpeg100 figconvrateloglog.jpg

% ... produce explicit log-log plot using Matlab's plot command
%     including a linear least-squares fit:
xdata = log10(vn0);
ydata = log10(venorminf);
p = polyfit(xdata, ydata, 1);
```

```
xmin = min(xdata); xmax = max(xdata);
dx = (xmax - xmin) / 128;
x = [xmin : dx : xmax];
y = polyval(p, x);
xtic = log10(vn0(1:2:end));
xticlab = num2cell(10.^xtic);

figure('DefaultAxesFontSize', 20);
H = plot(xdata,ydata,'o', x,y,'--');
set(H, 'LineWidth',3, 'MarkerSize',10);
set(gca, 'xtick',xtic, 'xticklabel',xticlab);
grid on;
str = ['lin. approx. with slope ', num2str(p(1))];
legend(H, 'infinity norm of true error', str);
xlabel('1 / h');
ylabel('log_{10} (||u - u_h||_\infty)');
print -djpeg100 figconvrateplot.jpg
```

References

[1] M. K. Gobbert, *Homepage including its sub-pages.* It can be found at the URL `http://www.math.umbc.edu/~gobbert`.

[2] M. K. Gobbert and A. Prohl, *A comparison of classical and new finite element methods for the computation of laminate microstructure*. Applied Numerical Mathematics, in press.

[3] ——, *A discontinuous finite element method for solving a multiwell problem*, SIAM Journal on Numerical Analysis, 37 (1999), pp. 246–268.

[4] M. K. Gobbert and C. Ringhofer, *A homogenization technique for the Boltzmann equation for low pressure chemical vapor deposition*. Submitted.

[5] ——, *Mesoscopic scale modeling for chemical vapor deposition in semiconductor manufacturing*. in: IMA Volumes in Mathematics and its Applications, Irene Gamba, David Levermore, Christian Ringhofer, editors, Springer-Verlag, accepted.

[6] M. K. Gobbert and C. A. Ringhofer, *An asymptotic analysis for a model of chemical vapor deposition on a microstructured surface*, SIAM Journal on Applied Mathematics, 58 (1998), pp. 737–752.

[7] M. Goossens, F. Mittelbach, and A. Samarin, *The LaTeX Companion*, Addison-Wesley, 1994.

[8] G. Grätzer, *Math into LaTeX: An Introduction to LaTeX and AMS-LaTeX*, Birkhäuser, 1996.

[9] N. J. Higham, *Handbook of Writing for the Mathematical Sciences*, SIAM, second ed., 1998.

[10] P. Ho. presented at the Schumacher Forum for Future Trends, San Diego, CA, February 1995, and private communication.

[11] A. Iserles, *A First Course in the Numerical Analysis of Differential Equations*, Cambridge Texts in Applied Mathematics, Cambridge University Press, 1996.

[12] L. Lamport, *LaTeX User's Guide and Reference Manual*, Addison-Wesley, second ed., 1994.

[13] Prof. Dr. Big Shot. Far Away University, personal communication.

[14] A. M. Raim and M. K. Gobbert, *Parallel performance studies for an elliptic test problem on the cluster tara*, Tech. Rep. HPCF–2010–2, UMBC High Performance Computing Facility, University of Maryland, Baltimore County, 2010.

[15] N. Sharma, *A comparative study of several numerical computational packages.* M.S. thesis, Department of Mathematics and Statistics, University of Maryland, Baltimore County, 2010.