Tools of the Trade:

The math graduate (and undergraduate) student's toolbox[*]

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Abstract

A very brief survey of various tools and resources that should be in a math student's arsenal.

1 Introduction

While preparing a talk for the Graduate Student Seminar, I collected a bibliography (initially short, but growing) and a list of resources that may be useful to mathematics students (graduate students, in particular, and to students in the sciences).

I would appreciate getting your feedback on this document, so that it may be expanded and improved in the future (as well as corrected and updated as needed) .

2 Survival

For a guide to surviving the wilds of graduate school, choosing a graduate program in mathematics and making the best of it, and getting your first job, see [25]. You may also be interested in the *Young Mathematicians Network (YMN)* `http://concerns.youngmath.net`, "a loose organization of mathematicians in the junior part of their careers founded in 1993" [38], which has similar information written by many contributors.

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3 Literature Search

When embarking on your research you may want to perform a literature search, find relevant references, or just find about the history of the problem you are studying. Some specialized tools for doing this are the Math Reviews database (available online as MathSciNet), the Zentralblatt für Mathematik database (available online as ZMath), and the Math Genealogy Project.

- MathSciNet - Mathematical Reviews (MR) online provides information on articles and books that contain new contributions to mathematical research. The online MR Database, contains MR information back to 1940, and is now maintained electronically. `http://www.ams.org/mathscinet`, see [16], and [1] for a guide.

- Zentralblatt MATH - ZMath Online Database is produced by the Berlin editorial office of FIZ Karlsruhe in cooperation with European academies and mathematical institutes. The ZMath Database contains about 2.8 million entries drawn from about 3500 journals and 1100 serials from 1868 to present `http://www.zentralblatt-math.org/zmath`.

- Mathematics Genealogy Project - The stated intent of this project is to compile information about all the mathematicians of the world. The service is provided by the NDSU Department of Mathematics, in association with the American Mathematical Society `http://genealogy.math.ndsu.nodak.edu`.

Of course there are also the general purpose databases such as the Science Citation Index and its web interface Web of Science `http://apps.isiknowledge.com` (except for the Math Genealogy Project, these are subscription based services, Auburn University library subscribes to MathSciNet and the Web of Science, and ZMath provides limited free access). You can use these databases to download citation information in a format compatible with your bibliographic software to populate your bibliographic database.

There are also many preprint servers (some are run by departments, or organizations such as national labs) and some by publishers who provide early access to papers accepted for publication by their journals. Most notably the arXiv `http://arxiv.org` is an e-print service in the fields of physics, mathematics, non-linear science, computer science, quantitative biology and statistics (usage depends on the culture in the field, it was started

by physicists, and is used by some mathematics disciplines, though not too much by applied mathematicians, or numerical analysts). A front-end to the arXiv operated by UC Davis is `http://front.math.ucdavis.edu`.

4 Writing Mathematics

During your academic career you will be writing, and communicating mathematics. You will be writing a thesis, writing papers, writing talks, giving talks, and preparing posters. You may be interested in an amusing article about math lingo [13] and a thought provoking article about teaching and writing for students is [2]. Advice about writing your first paper, as well as some general guidance about paper writing may be found in [27]. Additional more detailed information about paper writing and related topics is available in the two good books about writing mathematics (as well as preparing presentations and other related topics) [15] and [24]. See [3] for a review of these two books.

Among the topics treated in [15] are: Writer's Tools and Recommended Reading, Mathematical Writing, English Usage, When English Is a Foreign Language, Writing a Paper, Revising a Draft, Publishing a Paper, and Writing and Defending a Thesis.

Some older short booklets about writing are [4], [22], [26], and [36].

5 Writing Tools

The simplest way to start typesetting (beautiful looking) mathematics is to use LaTeX. You can use LaTeX to write your thesis, type handouts and exams, and to type your first paper (in fact LaTeX, actually XeLaTeX was used to typeset this short article).

You will be well served if you invest some time learning to use LaTeX, as well as learning how to create a bibliographic database and using a front-end to manage the database. If you are new to LaTeX, you should consider learning XeLaTeX instead. XeLaTeX is a new standard which will most likely replace LaTeX (note the two are very similar, so moving between the two should be fairly easy).

A history and overview of TeX and LaTeX can be found in [12] and a description of new developments in TeX and LaTeX, e.g. XeTeX and XeLaTeX and the direction things are heading can be found in [8], [9], and [10].

5.1 TEX

TEX is a typesetting language (in fact a programing language), created by Don Knuth in order to typeset mathematics, a description of TEX may be found in [17] and the actual program in [18]. Don Knuth also created a companion program to design fonts, see [19] and [20], and used it to designed the Computer Modern fonts (used to typeset this document, and many mathematical writings), see [21].

For a simple introduction to TEX see [34] and for a comprehensive and detailed manual, see [17]. Though if you are new to TEX you should also consider XETEX.

The learning curve for TEX and XETEX is quite steep, and for most of your writing LATEX or XELATEX should suffice.

TEX is a page description language, which you can use to describe the precise design and layout of your page, this in contrast to LATEX, but more on that below. TEX, while controlled by Don Knuth is in the public domain, it is cross platform, very powerful, but also complicated, and is not WYSIWYG (for the most part).

5.2 LATEX

LATEX is essentially a collection of markup commands (macros) for TEX that simplifies mathematical typesetting, it allows for various document types (e.g. report, article, and book), automatic numbering of equations and other structures (such as lemmas, theorems and definitions) and referencing these, creation of bibliographies and references to its entries, creation of tables of contents and indices.

LATEX is a logical markup language, it too is cross platform and in the public domain.

For a simple introduction to LATEX see [11] and [33] which is also available online at `http://www.ctan.org/pub/tex-archive/info/lshort/english/lshort.pdf` The classic LATEX manual, by its creator Leslie Lamport is [28] and my favorite, all around introduction and reference for LATEX is [23]. Another reference which also contains some advanced topics is [7].

5.3 Obtaining TEXand LATEX and add-ons

You can obtain TEX, XETEX, LATEX, and XELATEX, various add-ons and macro packages, and fron-ends from the The Comprehensive TEX Archive Network (CTAN) `http://www.ctan.org`. Additional information, tutorials

and TEX distributions (such as TEXLive and MacTEX) can be obtained from the TeX Users Group (TUG) web site `http://www.tug.org`.

You should consider a TEX distribution, or implementation (as they are called), e.g., TEXLive (which is available for all platforms), MacTEX (for the Mac), or MiKTEX for Windows. By installing such a distribution you will be installing TEX, XETEX, LATEX, and XELATEX, as well as various other tools (e.g, TEXworks on Windows, Mac and Linux, or TEXShop on the Mac). This is probably all you need, and will at least get you started. If needed you can always add additional packages later on.

For ease of use you should consider using a front-end. For the Mac TEXShop `http://www.uoregon.edu/~koch/texshop` is the most popular front-end. Inspired by TEXShop and gaining popularity is TEXworks `http://code.google.com/p/texworks` which is available for Windows, Mac, and Linux. The most popular distribution for windows is MiKTEX `http://www.miktex.org` which now comes with TEXworks. A comparison of TEX editors is available at `http://en.wikipedia.org/wiki/Comparison_of_TeX_editors`.

On CTAN you will find many processors, viewers/previewers, front-ends, and device drivers.

The current favorite presentation software is most likely Beamer, see `http://tug.ctan.org/tex-archive/macros/latex/contrib/beamer/doc/beameruserguide.pdf` for an online guide, or [7]. Mac users who like the additional features (and benefits) of Keynote can use the PDF to Keynote conversion program `http://www.cs.hmc.edu/~oneill/freesoftware/pdftokeynote.html` to convert their LATEX-generated PDF presentation to a Keynote presentation.

One bibliography manager for the Mac is BibDesk `http://bibdesk.sourceforge.net` A cross platform reference manager written in Java, and available for Mac, Windows, and Linux is JabRef `http://jabref.sourceforge.net`. A comparison of reference management software is available on the web `http://en.wikipedia.org/wiki/Comparison_of_reference_management_software`.

Quite often publishers have their own add-ons in the form of journal specific, or publisher specific style files.

5.4 Advanced Features

TEX, XETEX, LATEX, and XELATEX have many advanced features which allow creation of persentations, graphics, charts, tables, and diagrams, usage of colors, page (or slide) transitions, and creation of PDF and PS documents.

There is much that you can do with TEX, LATEX and PDF. To find out about advanced features, tricks consult [32] and [7] for general LATEX issues, [6] for issues with graphics, fonts, colors, pictures, and tricks, [5] for web publishing with LATEX and [31] for web publishing with PDF (this reference is a bit dated, but if you want to deal with raw PDF then it may provide the information you need). Slightly dated information about advanced TEX, installation and programming is [37].

6 Software Tools

When describing software tools we need to distinguish between open source and proprietary software and whether the software is free, or paid. This is sometimes referred to "free as in speech" (libre) and"free as in beer" (gratis).

You should keep an eye on the open source Python. Python is a scripting language which is quickly gaining favor among mathematicians and scientists. Under development are many libraries for data visualization and graphics, numerical computation, symbolic computation, and GUI development.

6.1 Computer Algebra System (CAS)

Computer algebra system are designed to do symbolic computation. Examples of some such systems are:

Proprietary systems

- Magma
- Maple
- Mathemetica
- MuPad

Open Source systems

- Axiom
- Maxima
- Sage `http://www.sagemath.org/`
- Singular

- SymPy (and iPython) http://code.google.com/p/sympy http://www.python.org

A list and comparison of computer algebra systems is available at http://en.wikipedia.org/wiki/Computer_algebra_system and http://www.symbolicnet.org.

One widely used (proprietary) CAS is Maple. Maple is a symbolic algebra package, a programming language (and a programming environment), and is described as an environment of choice for scientific and engineering problem-solving, mathematical exploration, data visualization and technical authoring. An introduction to Maple (as well as a quick reference card, a getting started guide and various tutorials) is available online, see [29].

6.2 Numerical Computing Environment

Numerical computing environments were designed primarily for floating point computations, though many of these systems have additional capabilities, most notably for graphics and scientific visualization (data visualization). Examples of such systems are:

Proprietary systems

- Matlab
- MathCad

Open Source systems

- GNU Octave http://www.gnu.org/software/octave
- R http://www.r-project.org
- Scilab http://www.scilab.org
- SciPy http://www.scipy.org

A list and comparison of numerical analysis software is available online http://en.wikipedia.org/wiki/List_of_numerical_analysis_software.

The most widely used and most highly regarded numerical computing environment is Matlab. Matlab originated as matrix laboratory, and was designed for matrix and vector computations (originally it had only one data type, a double complex array, this is still the default type). Matlab is also a programming language designed for mathematical computation, analysis, visualization, and algorithm development, it includes an integrated development environment. Matlab is widely used for prototyping, garphics, data

analysis, GUI development. It is described as "The Language of Technical Computing". Unique to Matlab are the numerous, discipline specific, toolboxes that provide additional specialized functionality. Matlab and companion toolboxes provide engineers, scientists, mathematicians, and educators with an environment for technical computing applications. A nice introduction to Matlab is [14], and a small pocket reference is [35] (expect a new addition in mid 2010 written by T. A. Davis), additional resources are available online [30].

6.3 Statistics Software

There are also packages designed specifically for statistical analysis, these include:

Proprietary systems

- Matlab (Statistics Toolbox)
- Minitab
- SAS
- SPSS

Open Source systems

- R `http://www.r-project.org`

See `http://en.wikipedia.org/wiki/Statistics_software` for a list of statistics software and comparison of statistics packages.

6.4 Virtual Machines

An emerging method for deploying software, and operating systems or operating environments are virtual machines. You may be able to use these in order to get specialized functionality or software running on your computer. One open source virtual machine is VirtualBox available from `http://www.virtualbox.org`. This may be particularly useful if you need a Unix-like environment and are a Windows user (you can run a Unix OS, Solaris OpenSolaris, FreeBSD, or OpenBSD, or a Unix-like OS, Gnu Linux). It also allows Mac OS X, Unix, and Gnu Linux users to run the Windows, and Vista OS.

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