

General Computer Science (CH08-320101) Fall 2016

T_EX/L^AT_EX Tutorial

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Abstract

This document is a tutorial for the use of T_EX/L^AT_EX in GenCS; it has two parts: The first is a brief general introduction to the concepts of the “documents-as-programs” paradigm and the T_EX typesetting system from the perspective of Computer Science. The second is a sequence of simple (but increasingly difficult) typesetting problems designed to practice the art of typesetting beautiful documents with L^AT_EX

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1 Programming Documents

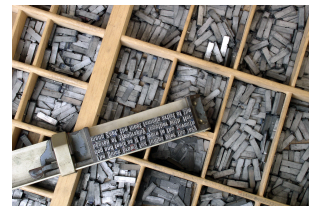
Idea: Even though documents should be thought of as sequences of characters with [markup](#) (and images, formulae, tables, etc.), we can also think of them as *programs that produce such characters with markup*. In some situations, this is profitable, e.g. when the documents have parts that can be computed from the rest, e.g. a table of contents, the section numberings, or indices. In such situations, the author does not need to type in the computable document fragments, but can just represent them by a command. A conversion program interprets such a “document program” (usually text interspersed with commands), executes all the commands, and outputs a document (without commands), which can then be read. The main advantage of the “documents as programs” paradigm is that the computed document fragments can never get out of sync with the rest of the document, which eases the maintenance burden over the document life-cycle.

There are various implementations of this idea, in this Section we present the $\text{T}_{\text{E}}\text{X}/\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ system, in which the `pdflatex` program is used to transform documents with macros into PDF. Systems like PHP do similar things for the Web.

The $\text{T}_{\text{E}}\text{X}$ Typesetting System

- ▷ **Definition 1.1** Typesetting is the process of creating the visual appearance of a document by assembling [glyphs](#) (visual representations of characters; also called [types](#)) on pages.

Since Gutenberg’s time (to ca. 1975), typesetting was done by assembling movable types (special metal positives of single letters) into lines and later into pages, which were inked and the printed; or using negatives to form cast-metal positives for printing.



- ▷ **Definition 1.2** $\text{T}_{\text{E}}\text{X}$ is a typesetting program designed by Donald Knuth in 1978. It combines movable types (character boxes) with macro programming.
- ▷ **Definition 1.3** The `pdftex` program reads a file of text marked up with $\text{T}_{\text{E}}\text{X}$ macros and outputs PDF.
- ▷ **Example 1.4 (Hello World in $\text{T}_{\text{E}}\text{X}$)** `pdftex` typesets the following $\text{T}_{\text{E}}\text{X}$ file

```
Hello, World \bye
```

The command sequence `\bye` stops `pdftex` and is not shown in the output.



Note that the “document program”

```
Hello, World \bye
```

the `pdftex` interprets all characters as “self-inserting characters”, i.e the character “a” is essentially a command that inserts a character “a” into the PDF (in the right font and size).

We have already seen one document program command used by `TEX` above, and there are many more. Most of them insert special characters into the document or change the formatting. But `TEX` goes much further, it allows the author to define commands as well. This makes the `TEX` format self-extensible, and into a very expressive special purpose programming language for documents.

T_EX Macros for Programming Documents

- ▷ `TEX` uses **command sequences** (words starting with “`\`”; also called **macros**) for special effects.
- ▷ **Example 1.5** `\bye` stops the formatter, `\alpha` prints α , `\int` prints \int, \dots
- ▷ Users can also define `TEX` macros as abbreviations via `\def`
- ▷ **Example 1.6** `\def\tdm{Text and Digital Media}` defines the macro `\tdm`.
We love the USC ‘`\tdm`’! expands to
“We love the USC “Text and Digital Media”!
- ▷ `TEX` macros can have arguments specify with `#1`, `#2`...: delimit with `{` and `}`
- ▷ **Example 1.7** with the macro `\def\tnwhat#1{Text and \textbf{#1}}` `\tnwhat{Beer}` expands to “Text and **Beer**”



`TEX` was invented by a mathematician, so it is not a surprise that it is the most capable tool for typesetting formulae — an art that only a select few professional typesetters (humans who put lead into rows) could do.

Mathematical Formulae in T_EX

- ▷ **Definition 1.8** T_EX has a **math mode** for formulae delimited with $(inline math)$ or $\[and \] (display math)$
- ▷ **Example 1.9** Some T_EX commands can be used everywhere: e.g. the Greek letters, α prints α , β prints β ,...
- ▷ **Example 1.10** Many T_EX commands only make sense in math mode: e.g. superscripts with $^$, e.g. x^3 gives x^3 , subscripts with $_$, e.g. x_{ij} gives x_{ij} , \int prints \int , $\frac{1}{2}$ prints $\frac{1}{2}$,...
- ▷ **Example 1.11** $\int_0^\infty f(\theta) d\theta$ expands to $\int_0^\infty f(\theta) d\theta$
- ▷ **Example 1.12** Use macros in math mode as well: $\def\frac#1#2{\#1\over #2}$
Then $\[1+\frac{2}{2+\frac{3}{3+\dots}}\]$ expands to

$$1 + \frac{2}{2 + \frac{3}{3 + \dots}}$$



One of the things that T_EX is useful for is to automate numbering of sections, subsections, footnotes, etc. For that T_EX offers some basic data structures. Here we introduce counters, and show how we can make simple sectioning macros from them.

T_EX Counters

- ▷ T_EX uses special macros as counters, \newcount , allocates a counter, \advance alters it, and \the references it.
- ▷ **Example 1.13** We define a sectioning macros

```
\newcount\seccount % allocate a new counter for sections
\newcount\subseccount % allocate a new counter subsections
\seccount0\subseccount0 % initialise both with 0
\def\section#1{ % begin macro definition
\advance\seccount by 1 % step the counter
\subseccount0 % reset the subsection counter
\textbf{\Large\the\seccount. #1} % section number and title
} % end macro definition
\def\subsection#1{\advance\subseccount by 1
\textbf{\large\the\seccount.\the\subseccount. #1}}
```

Anyone who is experienced in programming realizes that T_EX is not a modern programming language. But of course, it was conceived in 1978, the age of COBOL, and a lot has happened in programming language design since then. But even if it is relatively inconvenient and ugly code, it gets the job done.

We will now present a couple of internal macros that build up to more document automation that shows the advantages of programming documents: a serial letter macro.

T_EX Conditionals

- ▷ T_EX provides some **conditionals** for your use:
e.g. `\ifx` compares two macros, `\ifnum` compares two number, and `\ifmmode` tells you if you are in math mode.
`\if⟨cond⟩...⟨else⟩...⟨fi⟩` uses it.
- ▷ T_EX uses special macros for **user-defined conditionals**, `\newif\if⟨cond⟩` allocates a conditional, `⟨cond⟩true` and `⟨cond⟩false` alter it,

Programming a Chain Letter

- ▷ **Example 1.14 (A Parametric Reminder)**

```
\def\reminder#1#2{\hfill Bremen, \today\par\bigskip
\noindent Dear #1,\par\medskip\noindent
please be sure that you will not forget to come to the lecture
today. We are planning big things.\par\medskip\noindent
Sincerely,\par\bigskip\noindent #2\newpage}
```

- ▷ **Example 1.15 (Programming a Serial Letter)**

We can use arbitrary characters to delineate arguments in macro definitions.

```
\def\sletter#1,#2;{\def\first{#1}\def\second{#2}\def\empty{;}
\ifx\first\empty\else\reminder{#1}{Thomas \& Michael}
\ifx\second\empty\else\sletter#2,;\fi\fi}
\def\serialletter#1{\sletter #1;}
```

Also nothing prevents us from using recursion.

▷ **Example 1.16 (Making a Serial Letter)**

```
\serialletter{Mati, Anca, Isabel, Calin}
```



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ST_EX

Our serial letter example shows that with a bit of programming effort the self-extensibility of T_EX can be used to automate various document-oriented tasks, or style the documents for a given situation. Naturally, this brought forth a vibrant community that started swapping and re-using T_EX programs.

T_EX Macro Packages

- ▷ **Idea:** Separate out common macro definitions into a separate file and include that via `\input`. (So we can reuse them over multiple documents)
- ▷ **Actually:** many people have already done that.
- ▷ The AMS (American Mathematical Society) supplies AMST_EX: T_EX macros that make it more convenient to write Math (e.g. the `\frac` macro)
- ▷ Till Tantau supplies tikz (T_EX ist kein Zeichenprogramm): T_EX macros that allow you to draw images.
- ▷ Leslie Lamport supplies L^AT_EX, a set of T_EX packages and classes. pdf_latex is pdf_tex with the L^AT_EX package macros pre-loaded.
- ▷ The bibT_EX package handles bibliographic references.



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ST_EX

The most widely used macro package for T_EX is L^AT_EX, there are tens of thousands of macro packages that use the basic L^AT_EX infrastructure. L^AT_EX is the standard for high-end document formatting for scientific/technical documents nowadays. We now show a typical document as model for your own documents.

The Anatomy of a L^AT_EX Document

- ▷ **Example 1.17** A L^AT_EX file: main.tex

```
\documentclass{article} % use the article class (Journal Article)
```

```

\title{Anatomy of a {\LaTeX} Document} % specify the title,
\author{Michael Kohlhase\\Jacobs University Bremen} % author,
\date{\today} % and date
\begin{document} % start the document
\maketitle % make the title
\tableofcontents % make the table of contents
\section{Introduction}\label{sec:intro}
This is really easy, just start writing,
\section{Main Part}\label{sec:main}
We refer the reader to~\cite{Lampport:ladps94} for details.
But there should be at least one formula:
\[1+\frac{2}{2+\frac{3}{3+\ldots}}\]
\section{Conclusion}\label{concl:intro}
As we already said in Section~\ref{sec:intro} on
p. \pageref{sec:intro} this was not so bad was it?
\bibliographystyle{alpha}
\bibliography{example}
\end{document}

```

▷ Format it with `pdflatex main`(generates `main.aux` for references)



and the bibTeX database used in it

▷ Example 1.18 a bibTeX file `example.bib`

```

@BOOK{Lampport:ladps94,
  title = {LaTeX: A Document Preparation System, 2/e},
  publisher = {Addison Wesley},
  year = {1994},
  author = {Leslie Lamport}}

```

▷ Generate bibliography with `bibtex main`(it knows about `example.bib` from `main.aux`)

▷ run `pdflatex` twice (to get all the cross-references right)



The Result (generated parts in red)

Anatomy of a L^AT_EX Document

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November 30, 2016

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1. Introduction

This is really easy, just start writing,

2. Main Part

We refer the reader to [Lam84] for details. But there should be at least one formula:

$$1 + \frac{2}{2 + \frac{3}{3+\dots}}$$

3. Conclusion

As we already said in Section 1 on p. 1 this was not so bad was it?

References

[Lam94] Leslie Lamport, *L^AT_EX: A Document Preparation System*, 2/e, Addison Wesley, 1994.



2 Learning L^AT_EX by Example

The best way of learning L^AT_EX is to “program” a set of example documents. The problems below provide you with a set of problems that gradually introduce the salient features of L^AT_EX and should get you going for most of the documents you will need initially.

Solutions to these problems are available at

<http://kwarc.info/teaching/GenCS1/latex-tutorial-with-solutions.pdf>.

But you should try them alone first to maximize learning.

There are good T_EX, L^AT_EX, and bibT_EX tutorials on the Web which you should use for solving these problems, but also consult [?, ?] and (if you want to drink from the source and know the gory details) [?] (als known as the T_EX bible). The course instructor and the TAs will be happy to help you and get you unstuck, when necessary. But you should try to solve them by yourself first to make progress.

But before you can start, you will need a L^AT_EX installation on your computer, so that you can format your documents and practice. For UNIX-based systems (e.g. linux and Mac OS X), the TeXLive distribution is currently the best (see <http://www.tug.org/texlive/> for details and installation instructions). For Windows, you should use MikTeX (see <http://miktex.org>).

You should not expect to be able to get through all the problems in the tutorial itself, indeed, if you manage the first six or seven, then you are on a very good track. The remaining ones are for self-study in the next weeks. The introduce the finer points of T_EX/L^AT_EX.

2.1 L^AT_EX Basics

Problem 0.1 (Hello World in L^AT_EX)

Write a “hello world” document in L^AT_EX, i.e. a document that only contains the two words “Hello World”.

Solution: Easy, we only need to declare the document class with `\documentclass`, and add the words “Hello World” in the `document` environment.

```
\documentclass{article}
\begin{document}
Hello World
\end{document}
```

Problem 0.2 (A L^AT_EX with Title)

Write a document with a title, the date of today, and yourself as an author (with Jacobs University as the affiliation) It should look like this:

The Evolution of Abstract Nonsense

General Computer Scientist
Jacobs University Bremen
gc.scientist@jacobs-university.de

23. July 2011

Solution: We use the `\maketitle` macro that makes a title block from information specified via the `\author`, `\date`, and `\title` macros. Note that the three latter are traditionally put into the document preamble, i.e. before the `\begin{document}`.

```
\documentclass{article}
\author{General Computer Scientist\\
       Jacobs University Bremen\\
       \texttt{gc.scientist@jacobs-university.de}}
\date{23. July 2011}
\title{The Evolution of Abstract Nonsense}
\begin{document}
\maketitle
\end{document}
```

Problem 0.3 (A \LaTeX Document with Sections and Table of Content)

Extend the document from Problem 0.2 with a couple of sections and subsections of your choice via the `\section` macro for sections and (correspondingly) `\subsection` for subsections.

Cross-reference various of the sections using the `\label` and `\ref` macros.

Hint: When you use the `hyperref` package (use `\usepackage{hyperref}` at the very end of the preamble), then the references become hyper-references (clickable in the PDF). Try this on your document!

Solution: This is pretty straightforward using the macros above, but note that you have to run `pdflatex` twice to bet the cross-references straight.

```
\documentclass{article}
\author{General Computer Scientist\\
       Jacobs University Bremen\\
       \texttt{gc.scientist@jacobs-university.de}}
\date{23. July 2011}
\title{The Evolution of Abstract Nonsense}
\usepackage{hyperref}
\begin{document}
\maketitle
\tableofcontents\newpage
```

```
\section{Introduction}\label{sec:intro}
This is a very important topic, you will have to write paper all the time.
```

The introduction usually ends with a sentence of what will come in the paper. Something

like. We will develop the main matter in Section~\ref{sec:main}; Section~\ref{sec:concl} concludes the paper.

```
\section{Main Matter}\label{sec:main}
\subsection{The First Result}\label{sec:main:first}
\subsection{The Second One}\label{sec:main:second}
\subsection{The Final Result}\label{sec:main:last}

\section{Conclusion}\label{sec:concl}
As we have motivated in the introduction (see Section~\ref{sec:intro}) we are solving an
important problem here. The results from~\ref{sec:main:first} to~\ref{sec:main:last},
solve the problem.
\end{document}
```

Problem 0.4 (Complex Tables)

Write the GenCS Grading Table on the right using the `tabular` environment. Note that the first column in this table is left aligned, the second one centered, and the third one is 4 cm long and allows multi-line content. Note furthermore, that there is a double line after the first row.

| Component | % | Comment |
|----------------|----|--------------------------------|
| Monday Quizzes | 30 | to make you study continuously |
| Homeworks | 20 | practice |
| Midterm Exam | 20 | to see if you excel at CS |
| Final Exam | 30 | to prove that |

The `tabular` environment takes a format string in the first argument. Here `|` makes a table cell border, `l` and `c` specify left/centered alignment, and `p{4cm}` a paragraph box 4 centimeters wide. `&` separates columns, `\\` makes a new table row, and `\hline` a horizontal cell border.

Solution:

```
\begin{tabular}{|l|c|p{4cm}|}\hline
Component & \% & Comment\\\hline\hline
Monday Quizzes & 30 & to make you study continuously\\\hline
Homeworks & 20 & practice\\\hline
Midterm Exam& 20 & to see if you excel at CS\\\hline
Final Exam & 30 & to prove that\\\hline
\end{tabular}
```

Problem 0.5 (Creating a Bibliography)

Extend the paper from `?prob.docsections?` with three references: your Bachelor's thesis, your first journal article, and your first book (make them up if you have not written those). You should use the `bibTeX` program for this.

Hint: It is generally a good idea to start a `bibTeX` database of the scientific papers and books you have read early, so that you can cite them in your papers later.

Hint: There is a relatively new successor to `bibTeX` called `biblatex`, you may want to eventually have a look at that.

Solution: Here is a sample `bibTeX` file for your instructor. Note that the entry for the article is rather verbose, to show you what is possible.

```

@PHDTHESIS{Kohlhase:amosho94,
  author = {Michael Kohlhase},
  title = {A Mechanization of Sorted Higher-Order Logic Based on the Resolution Principle},
  school = {Universit{"a}t des Saarlandes},
  year = {1994},
  url = {http://kwarc.info/kohlhase/papers/diss.pdf}}

@BOOK{Kohlhase:omdoc1.2,
  title = {\textsc{OMDoc} -- An open markup format for mathematical documents [Version 1.2]},
  publisher = {Springer Verlag},
  year = {2006},
  author = {Michael Kohlhase},
  number = {4180},
  series = {Lecture Notes in Artificial Intelligence},
  url = {http://omdoc.org/pubs/omdoc1.2.pdf}}

@article{KohDavGin:psewads11,
  journal = {Procedia Computer Science},
  author = {Michael Kohlhase and Joe Corneli and Catalin David and Deyan Ginev and
    Constantin Jucovschi and Andrea Kohlhase and Christoph Lange and
    Bogdan Matican and Stefan Mirea and Vyacheslav Zholudev},
  title = {The Planetary System: Web 3.0 \& Active Documents for STEM},
  issuetitle = {Proceedings of the International Conference on Computational Science (ICCS)},
  editor = {Mitsuhisa Sato and Satoshi Matsuoka and Peter M. Sloot and G. Dick van Albada and
    Jack Dongarra},
  pages = {598--607},
  venue = {Nanyang Technological University, Singapore},
  eventdate = {2011-06-01/2011-06-03},
  note = {Finalist at the Executable Papers Challenge},
  year = 2011,
  volume = 4,
  url = {https://svn.mathweb.org/repos/planetary/doc/epc11/paper.pdf},
  publisher = {Elsevier},
  doi = {10.1016/j.procs.2011.04.063},
  keywords = {conference},
  pubs = {mkohlhase,c david,dginev,akohlhase,clang, bmatican,smirea,vzholudev,projects/planetary

```

To use these citations, just add `\cite{Kohlhase:amosho94}`, `\cite{Kohlhase:omdoc1.2}`, `\cite{KohDavGin:psewads11}` in appropriate places.

2.2 L^AT_EX Math

Problem 0.6 (Simple Math Formulae)

The solutions of the quadratic equation $ax^2 + bx + c = 0$ are $\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$.

Write this in L^AT_EX

Solution:

The solution of the quadratic equation $ax^2+bx+c=0$ is $\frac{-b\pm\sqrt{b^2-4ac}}{2a}$.

Problem 0.7 (A more complex Math Formula)

The Taylor series of $\sqrt{1+x}$ about $x=0$ converges for $|x| \leq 1$ and is given by

$$\sqrt{1+x} = \sum_{n=0}^{\infty} \frac{(-1)^n 2n!}{(1-2n)(n!)^2 (4^n)} x^n = 1 + \frac{1}{2}x - \frac{1}{8}x^2 + \frac{1}{16}x^3 - \frac{5}{128}x^4 + \dots$$

Write this in \LaTeX , but note that the last multi-equation is in “display style” (i.e. centered and with bigger fonts).

Solution:

The Taylor series of $\sqrt{1+x}$ about $x=0$ converges for $|x| \leq 1$ and is given by

```
\[\sqrt{1+x} =
\sum_{n=0}^{\infty} \frac{(-1)^n(2n)!}{(1-2n)(n!)^2(4^n)}x^n =
1 + \frac{1}{2}x - \frac{1}{8}x^2 + \frac{1}{16}x^3 - \frac{5}{128}x^4 + \dots
\]
```

Problem 0.8 (Matrices)

Write the following multiplication of 2×2 matrices in \LaTeX :

$$\begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \begin{pmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{pmatrix} = \begin{pmatrix} a_{11}b_{11} + a_{12}b_{21} & a_{11}b_{12} + a_{12}b_{22} \\ a_{21}b_{11} + a_{22}b_{21} & a_{21}b_{12} + a_{22}b_{22} \end{pmatrix}$$

Solution:

Multiplication of 2×2 matrices:

```
\[\left(\begin{array}{cc}
a_{11} & a_{12} \\
a_{21} & a_{22}
\end{array}\right)\left(\begin{array}{cc}
b_{11} & b_{12} \\
b_{21} & b_{22}
\end{array}\right) =
\left(\begin{array}{cc}
a_{11}b_{11} + a_{12}b_{21} & a_{11}b_{12} + a_{12}b_{22} \\
a_{21}b_{11} + a_{22}b_{21} & a_{21}b_{12} + a_{22}b_{22}
\end{array}\right)\]
```

Problem 0.9 (Displayed Equations)

Write the formula from ?prob.math-display? as an equation array using the `eqnarray` environment and reference the second equation in the text, so that it looks like

$$\sqrt{1+x} = \sum_{n=0}^{\infty} \frac{(-1)^n 2n!}{(1-2n)(n!)^2 (4^n)} x^n \tag{1}$$

$$= 1 + \frac{1}{2}x - \frac{1}{8}x^2 + \frac{1}{16}x^3 - \frac{5}{128}x^4 + \dots \tag{2}$$

Now we reference the partial equations: the first with (1) and the second with (2). Note that there is a variant `eqnarray*` that does not make the equation numbers.

Solution:

```
\begin{eqnarray}
\sqrt{1 + x}
& = & \label{eq:first}
\sum_{n=0}^{\infty} \frac{(-1)^n(2n)!}{(1-2n)(n!)^2(4^n)}x^n \\
& = & \label{eq:second}
1 + \frac{1}{2}x - \frac{1}{8}x^2 + \frac{1}{16}x^3 - \frac{5}{128}x^4 + \dots
\end{eqnarray}
```

Now we reference the partial equations the first equation one with (`\ref{eq:first}`) and the second one with (`\ref{eq:second}`).

2.3 L^AT_EX Macros

Problem 0.10 (Matrix Macros)

You can make T_EX macros to make your life easier.

1. Write a macro `\ttmatrix` that takes four arguments and writes a 2×2 matrix: for example `\ttmatrix{a}{b}{c}{d}` prints $\begin{pmatrix} a & b \\ c & d \end{pmatrix}$.
2. Write a macro `\gttmatrix` that takes a single argument variable and prints a generic 2×2 matrix: for example `\gttmatrix{a}` prints $\begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}$.
3. With these macros write the matrix multiplication from `?prob.math-matrices?` more succinctly.

Solution: We use the `\newcommand` macro for this, it takes an

1. `\newcommand{\ttmatrix}[4]{\left(\begin{array}{cc} #1 \\ #3 \end{array}\right)}`
2. `\newcommand{\gttmatrix}[1]{\ttmatrix{#1_{11}}{#1_{12}}{#1_{21}}{#1_{22}}}`
3. `\gttmatrix{a}\gttmatrix{b} =`
`\ttmatrix{a_{11}b_{11} + a_{12}b_{21}}{a_{11}b_{21}+a_{12}b_{22}}`
`{a_{21}b_{12} + a_{22}b_{21}}{a_{21}b_{21}+a_{12}b_{22}}`