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Abstract

This document is a tutorial for the use of T_EX/I_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 I_EXEX

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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 TEX/LATEX 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 T_FX 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 T_EX 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 TEX macros and outputs PDF.
- ▷ Example 1.4 (Hello World in TEX) pdftex typesets the following TEX file

Hello, World \bye

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



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Note that the "document program"

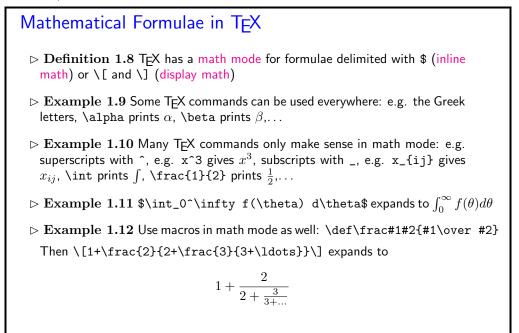
Hello, World \bye

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.

TEX 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 ∫,... □ 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}} \text{\therefore the there of the there is the macro \def\\there of the there is the macro \def\\there of the there is the there of the there is the macro \def\\there of the there is the there of the there is the there is the there is the there is the there of the there is the

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.



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.

3

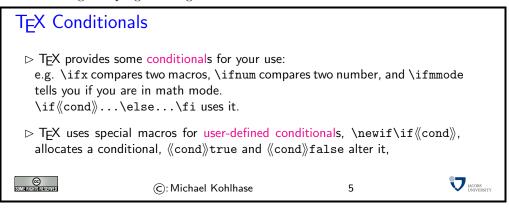
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Anyone who is experienced in programming realizes that TEX is not a modern programming language. But of course, it was conceived in 1978, the age of COBOL, and a lot has happened in programming language design since then. But even if it is relatively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



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}
```

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.

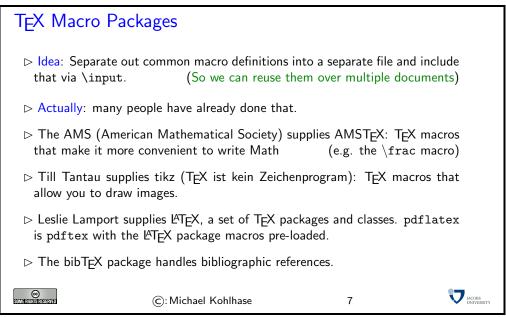
▷ Example 1.16 (Making a Serial Letter)

\serialletter{Mati, Anca, Isabel, Calin}

©

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```

Our serial letter example shows that with a bit of programming effort the self-extensibility of TEX 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 TEX programs.



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.

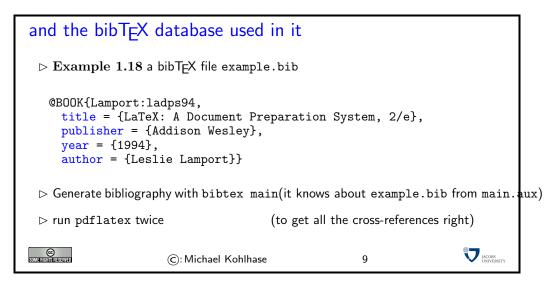
```
The Anatomy of a LATEX Document

> Example 1.17 A LATEX file: main.tex

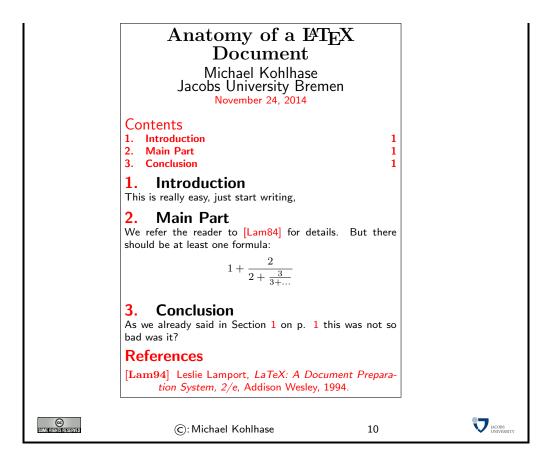
\documentclass{article} % use the article class (Journal Article)
\title{Anatomy of a {\LaTeX} Document} % specify the title,
\author{Michael Kohlhase\\Jacobs University Bremen} % author,
\date{\today} % and date
\begin{document} % start the document
\maketitle % make the title
\tableofcontents % make 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{Lamport: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)
```



The Result (generated parts in red)



References

[KD03] Helmut Kopka and Patrick W. Daly. Guide to \(\mathbb{L}T_{EX}\) (Tools and Techniques for Computer Typesetting). Addison-Wesley Professional, 4 edition, 2003.

[Knu84] Donald E. Knuth. The TEXbook. Addison Wesley, 1984.

[Lam94] Leslie Lamport. LaTeX: A Document Preparation System, 2/e. Addison Wesley, 1994.

2 Learning LATEX by Example

The best way of learning LATEX 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 LATEX 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 TEX, LATEX, and bibTEX tutorials on the Web which you should use for solving these problems, but also consult [Lam94, KD03] and (if you want to drink from the source and know the gory details) [Knu84] (als known as the TEX 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 LATEX installation on your computer, so that you can format your documents and practice. For UNIX-based systems (e.g. linux and MacOSX), 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 TFX/LATFX.

2.1 LaTeX Basics

Problem 2.1 (Hello World in I⁴TEX)

Write a "hello world" document in LATEX, 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 2.2 (A LATEX 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 \maketite 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 2.3 (A LATEX Document with Sections and Table of Content)

Extend the document from ?prob.doctitle? 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}
conludes 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 2.4 (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.

%	Comment
30	to make you study contin-
	uously
20	practice
20	to see if you excel at CS
30	to prove that
	30 20 20

The tabular environment takes a format string in the first argument. Here | makes a table cell border, 1 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}{|1|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 2.5 (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,cdavid,dginev,akohlhase,clange,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 LATEX Math

Problem 2.6 (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 LATEX

Solution:

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

Problem 2.7 (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 IATEX, 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 $|x|\leq1$ 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 2.8 (Matrices)

Write the following multiplication of 2×2 matrices in LATEX:

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

Solution:

```
Multiplication of $2\times2$ 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_{21}b_{12}\\
    a_{21}b_{12}\\
    a_{21}b_{12}\\
    a_{21}b_{12}\\
    a_{21}b_{12}\\
    a_{21}b_{21}\\
    a_{21}b_{21}b_{21}\\
    a_{21}b_{21}b_{21}\\
    a_{21}b_{21}b_{21}b_{21}\\
    a_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21}b_{21
```

Problem 2.9 (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

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

$$= 1 + \frac{1}{2}x - \frac{1}{8}x^2 + \frac{1}{16}x^3 - \frac{5}{128}x^4 + \dots$$
 (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}\cdot x^2 + \frac{1}{16} x^3 - \frac{5}{128} x^4 + \frac{eq}{eq}.  Now we reference the partial equations the first equation one with (\ref{eq:first}) and the second one with (\ref{eq:second}).
```

2.3 LATEX Macros

Problem 2.10 (Matrix Macros)

You can make TFX 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. $\mbox{\mbox{$\mbox{}\mbox{$\mbox{}\mbox{$\mbox{}\box{$\mbox{$
- 2. $\mbox{\mbox{$\backslash$} mewcommand{\gttmatrix}[1]{$\langle \#1_{11}\}{\#1_{12}}{\#1_{21}}{\#1_{22}}}}$
- 3. $\gtmatrix{a} \gtmatrix{b} = \\ \gtmatrix{a_{11}b_{11} + a_{12}b_{21}}{a_{11}b_{21}+a_{12}b_{22}} \\ \gtmatrix{a_{11}b_{12} + a_{22}b_{21}}{a_{21}b_{21}+a_{12}b_{22}} \\$