

Different techniques for visualisation of combinatorial maps

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Abstract

The combinatorial maps is a combinatorial topological structure. It represents a graph embedded into the surface. This project aims to search for different techniques for visualisation of combinatorial maps. The combinatorial map has many features, and the methods implemented in the project come from them. In order to attract more people learning the structure, the methods are collected as a tool in JAVASCRIPT. The methods and the visualiser are evaluated successfully though there are some problems. Some of the methods still can be improved in the future.

Keywords:Combinatorial maps, visualisation, topological structure

Note

Some content in section (5) has been based on the content written in my Mini-project report[10].

Source code

The source code for this project can be found at <https://git-teaching.cs.bham.ac.uk/mod-msc-proj-2018/txh755>.

Declaration

I hereby declare that this thesis is my own work and effort and that it has not been submitted anywhere for any award. Where other sources of information have been used, they have been acknowledged.

<insert data and location>

<insert full name>

Contents

CHAPTER 1

Introduction

1.1 Motivation

Combinatorial map is a combinatorial topological structure which describe a graph embedded in a surface. It includes three components vertices, faces, and edges, which are represent by the permutations of darts (half-edges). There are three notations of the permutations two-notation, one-line notation and cycle notation. All of the notations are used to represent the each component of the map, while, cycle notation and one-line are mentioned in the calculation frequently and two-line notation is utilised into visualisation generally. There are some strict constrains of a map, so that only if two maps are isomorphic by a homeomorphism of the underlying surfaces, they could be conjugation equivalent.

The drawing a topological structure is heated topic[0], while, the visualisation of combinatorial maps is rarely mentioned. This project aims to build a tool for visualising the combinatorial maps by using different techniques. Firstly, the tool could make the concept more accessible and interesting, which is quite important for the beginners who are new to the relevant knowledge. As the mean time, for those researchers who conduct related research, this tool could help them improve their efficiency and productivity effectively.

Due to the final goal of the project is drawing the map automatically, the project will pay more attention on the layout of the map. The spanning tree and dual maps are discussed as the based sketch of the structure when visualising the maps.

1.2 Tool structure

The Tool has two pages introduction and visualiser. The first page is to introduce the combinatorial maps and relevant knowledges involved in the visualiser.

The second page has three units. The head unit is also an introduction that offer the details of the page, namely, what the pages consist of, how to operate each unit and the representation of each terminology. The input unit includes three types of input. In the first section some examples are supported for users to experience. For the second section, users can try or validate their own specific sample. Users can also play with the last section for generation a random map by only entering the number of darts. The last unit is the output part which contains the visualisation of each component of combinatorial maps with cycle and one-line notations, the other information of the maps and the final results of the methods. Each results can be clicked to view more details.

1.2.1 Report structure

The report structured as follow. Section 2 provides the related knowledge of combinatorial maps, as well as its purpose and significance. Section 3 describes the achievement in this area, the former method was proposed by others and the later method was what I have done in the last semester mini-project. Section 4 gives more specifications of the tool. The ideas of visualisation of maps and the construct of the tool are involved in section 5. Section 6 evaluates the methods and the system. Section7 details the achievements, issues and improvement of the system. Appendix A shows the file structure of the project.

CHAPTER 2

Background

Combinatorial map is a topological structure describing the rotational graph embedded in the surface. It includes three components: vertices, edges and faces. Each of them is composed of permutations of darts. This section will introduces these concepts and terminology.

2.1 Permutations

Permutation is arranging all members of a set or a sequence with a certain order, and each order called a permutation. For example, the set 1,2 have two permutations (1 2) and (2 1). Each permutation is written as tuple. Three notations can be used to represent this concept, two-line notation, one-line notation and cycle notation.

Subsection heading

As the name implies, this notation uses two rows two indicate the permutations. The first row is the list of elements in set , for instance, the first row of set 1,2,3 would be (1 2 3). Meanwhile, the second line is its permutations, hence the second line for the example is (3 2 1). The permutation (3 2 1) can be written as $p = \begin{pmatrix} 1 & 2 & 3 \\ 3 & 2 & 1 \end{pmatrix}$. From the example we could see that that this notation shows permutations quite clear and intuitive. The permutation which is represented by this notation can be drew as the ???. In the figure 1, it is obvious that the permutation is a mapping for set to itself, so that it can be defined as a function p . Take the example (3 2 1) again, the second line of it can be written as $(p(1), p(2), p(3))$ where $p(1) = 3$, $p(2) = 2$ and $p(3) = 1$, as well as, the whole formula for the example can be rewritten as $p = \begin{pmatrix} 1 & 2 & 3 \\ p(1) & p(2) & p(3) \end{pmatrix}$.

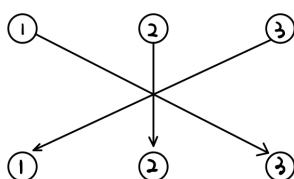


Figure 2.1: Two-line notation for permutation $p = (3 2 1)$, in which $p(1) = 3$, $p(2) = 2$, and $p(3) = 1$.

Subsubsection heading

Mauris rutrum volutpat massa. Suspendisse potenti. Nam varius. Fusce nec leo. Morbi vestibulum augue ac justo. Vivamus in odio in turpis pharetra blandit. Mauris aliquet

ullamcorper libero. Integer quam mi, venenatis ut, tristique ut, tempus at, ipsum. Donec malesuada. In quis tellus et ipsum hendrerit imperdiet. Vivamus sapien ipsum, suscipit sed, gravida a, lacinia laoreet, ipsum. Quisque augue. Nulla justo enim, auctor at, hendrerit nec, porttitor non, urna. Duis tincidunt tincidunt dui. Lorem ipsum dolor sit amet, consectetur adipiscing elit. Suspendisse potenti. Aenean sit amet mauris. In luctus purus nec lorem. Proin orci tortor, tempus sit amet, molestie hendrerit, placerat egestas, tellus.

CHAPTER 3

Experiments

3.1 LaTeX Typesetting By Example

This section demonstrates a basic set of LaTeX formatting commands and shows how they look like in this template. For comparison of the typeset output with the input document refer to the code listing starting on page ??.

The content presented here is based on similar text by Phil Farrell¹ and Harvey Gould². For further reading on the possibilities of this template please refer to the documentation: `TemplateDocumentation.pdf`.

3.1.1 Plain Text

Type your text in free-format; lines can be as long or as short as you wish. You can indent or space out your input text in any way you like to highlight the structure of your manuscript and make it easier to edit. LaTeX fills lines and adjusts spacing between words to produce an aesthetically pleasing result.

Completely blank lines in the input file break your text into paragraphs. Several command exist to change the font for a single character, word, or set of words. Simply enclose the word and within braces of the formatting command, *like this*. A font changing command not enclosed in braces, like the change to **bold here, keeps that change in effect until the end of the document or until countermanded by another font switch, like this change back to** the default font.

3.1.2 Font shapes

The default font in the template is Latin Modern (`lmodern`). It includes *italics*, **boldface**, *slanted*, SMALL CAPS and **monospaced** fonts as well as the corresponding sans serif variants of the same font family **sans serif**, *italics*, **boldface** and *slanted*. Note that for other fonts not all font shapes may be available.

3.1.3 Quotation and Citations

LaTeX provides the ‘quote’ and ‘quotation’ environments for typesetting quoted material or any other text that should be slightly indented and set off from the normal text.

However, if the text shall not just be indented but rather be a real quotation with a citation of the origin, then the commands ‘enquote’ for inline quotes and ‘blockquote’ for multi line quotes are more appropriate. The first is used to highlight the commands

1 <https://pangea.stanford.edu/computing/unix/formatting/latexexample.php>

2 <http://sip.clarku.edu/tutorials/TeX/>

in this section and the latter in the following text, which is a direct quotation from the documentation of the package *csquotes*:

This command determines the length of the text. If the length exceeds a certain threshold, the text will be typeset in display mode, i. e., as a block quotation. If not, `\blockquote` will behave like `\textquote`. Depending on the threshold type option, the threshold may be based on the number of lines required to typeset the text or on the number of words in the text. (*csquotes.pdf*)

The standard command for citations is `\cite` which may have a prenote argument for adding a page number or something similar. To show how a citation is typeset we cite here a book about LaTeX [**companion**]. Further commands such as `\parencite` [**companion**] and `\textcite` **companion** allow a different typeset of the citation. The resulting bibliography is printed out on `??`. Refer to the *biblatex* manual for further details on citation commands and modifications on the printout and the section on *biblatex* in the template documentation.

3.1.4 References

So far, in this text chapter and section headings, paragraphs (`??`), font changes (`??`) and citations (`??`) were demonstrated and in this section the use of references. Note that here the command `\cref` was used instead of the standard `\ref`.

The following sections show lists, tables and math.

3.1.5 Lists

LaTeX has three types of lists with the environment names *itemize*, *enumerate* and *description*. All lists have a separation between each item, to improve the reading of item texts spanning several lines. This item text can contain multiple paragraphs. These paragraphs are appropriately spaced and indented according to their position in the list.

- The ‘itemize’ sets off list items with *bullets*, like this.
 - Of course, lists can be nested, each type up to at least four levels. One type of list can be nested within another type.
 - Nested lists of the same type will change style of numbering or *bullets* as needed.
1. The ‘enumerate’ environment numbers the list elements.

This is a new paragraph in the item text, which is not intended as in the normal text but separated from the previous paragraph.
 2. The enumeration scheme changes with each nesting level
 - a) as shown in this nested enumerated list item.

Don’t forget to close off all list environments with the appropriate `\end{...}` command. Indenting `\begin{...}`, `\item`, and `\end{...}` commands in the input document according to their nesting level can help clarify the structure.

3.1.6 Tables

Tables are a little more difficult. One can achieve even the most complex and fancy layout, even spanning over multiple pages, but the code to create these tables is not necessarily the best readable one.

Table ?? is a very simple table showing data lined up in columns, where each column width is automatically calculated by LaTeX. Notice that the tabular is centered with `\centering` and printed in a smaller font to achieve a clear distinction to the normal text. The title is created above the tabular with `\captionabove`.

Table 3.1: Numbers of Computers in the department, By Type.

Mac (Apple)	2
Windows XP, 7	60
Linux (Server)	10

?? on ?? demonstrate the creation of a pleasant appearing table, which helps to read the table without attracting too much attention by the use of shaded colors. The caption uses the additional short caption in square brackets [], which is used in the list of tables, see ??.

Table 3.2: Comparison of the mean-field predictions for the critical temperature of the Ising model with exact results and the best known estimates for different spatial dimensions d and lattice symmetries.

lattice	d	q	T_{mf}/T_c
square	2	4	1.763
triangular	2	6	1.648
diamond	3	4	1.479
simple cubic	3	6	1.330
bcc	3	8	1.260
fcc	3	12	1.225

The design and creating of complex tables is shown in much greater detail in the documentation of this template.

3.1.7 Mathematical Equations

Simple equations, like x^y or $x_n = \sqrt{a+b}$ can be typeset right in the text line by enclosing them in a pair of single dollar sign symbols. Don't forget that if you want a real dollar sign in your text, like \$2000, you have to use the `\$` command.

A more complicated equation should be typeset in *displayed math* mode using `\[... \]`, like this:

$$z \left(1 + \sqrt{\omega_{i+1} + \zeta - \frac{x+1}{\Theta+1}y+1} \right) = 1$$

The `equation` environment displays your equations, and automatically numbers them consecutively within your document, like this: We can give an equation a label so that we can refer to it later.

$$E = -J \sum_{i=1}^N s_i s_{i+1}, \quad (3.1)$$

Equation (??) expresses the energy of a configuration of spins in the Ising model.¹

For more complex formulas it may be necessary to do some fine tuning by adding small amounts of horizontal spacing,

`\,` small space `\!` negative space

as is done in eq. (??).

$$\iiint_S [u \nabla^2 v + (\nabla u, \nabla v)] \, d^3 V = \iint_S u \frac{\partial v}{\partial n} \, d^2 A \quad (3.2)$$

We also can also align several equations

$$\dot{q}_i = \frac{\partial H}{\partial p_i} \quad (3.3)$$

$$\dot{p}_i = -\frac{\partial H}{\partial q_i} \quad (3.4)$$

number them as subequations

$$\dot{q}_i = \frac{\partial H}{\partial p_i} \quad (3.5a)$$

$$\dot{p}_i = -\frac{\partial H}{\partial q_i} \quad (3.5b)$$

or with only a single number

$$\begin{aligned} \dot{q}_i &= \frac{\partial H}{\partial p_i} \\ \dot{p}_i &= -\frac{\partial H}{\partial q_i} \end{aligned} \quad (3.6)$$

Many further possibilities of displaying equations exist.

¹ It is necessary to process (typeset) a file twice to get the counters correct.

Common Greek letters

These commands may be used only in math mode. Only the most common letters are included here.

$$\alpha, \beta, \gamma, \Gamma, \delta, \Delta, \varepsilon, \zeta, \eta, \theta, \Theta, \kappa, \lambda, \Lambda, \mu, \nu, \xi, \Xi, \pi, \Pi, \rho, \sigma, \tau, \phi, \Phi, \chi, \psi, \Psi, \omega, \Omega$$

3.1.8 Literal text

It is desirable to print program code exactly as it is typed in a monospaced font. Use `\begin{lstlisting}` and `\end{lstlisting}` as in the following example:

```
1 double y0 = 10; // example of declaration and assignment statement
2 double v0 = 0;  // initial velocity
3 double t = 0;   // time
4 double dt = 0.01; // time step
5 double y = y0;
```

Two styles are defined in this template: `lstStyleCpp` and `lstStyleLaTeX`.

A complete file can be printed with listings using the command `\lstinputlisting`, see ?? for an example.

3.1.9 Figures

Figures with captions are included in the `figure` environment in order to position the graphic inside the text. The size should be given in relation to natural text size. It is recommended to use a percentage value of the `\textwidth`. This size should not exceed 80 % of the text width.

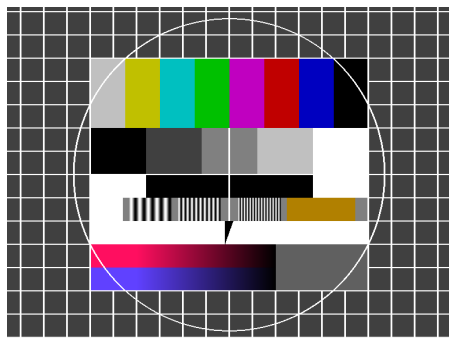


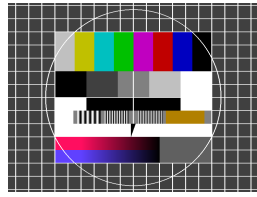
Figure 3.1: Test image for television (Origin of the image: <http://de.wikipedia.org/wiki/Testbild>).

All possibilities of grouping pictures side by side, on top or in matrices can be realized. Each subfigure is created in the same way as a graphic inside a figure, just enclosed by a figure environment, as shown in ??.

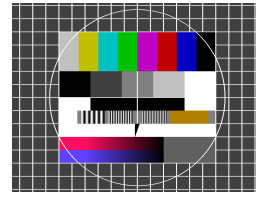
For complex subfigure constructs and correct alignment of the subcaption the `floatrow` provides powerful commands.

3.1.10 Index

An index is easy to create with LaTeX, but should only be done if the time is available to do it right, since it requires substantial work to create an index which is really useful



(a) The first subfigure.



(b) The second subfigure.

Figure 3.2: Demonstration of the *subfigure* environment inside a figure environment

for the reader.

A word is added to the index with the command `\index{word}` and these indexed words can be grouped with `\index{group!word}`. Within this document some index commands are inserted below the section headers of this tutorial for the purpose of demonstrating the indexing. The resulting index is displayed on page ??.

3.1.11 Code

```

1 % !TeX encoding=utf8
2 % !TeX program = pdflatex
3 % !TeX spellcheck = en-US
4
5 % LaTeX Tutorial for the latexthesistemplate
6 % based on
7 % - https://pangea.stanford.edu/computing/unix/formatting/latexexample.php
8 % - http://sip.clarku.edu/tutorials/TeX/
9 % and extended and modified by Matthias Pospiech
10
11 \ifcsdef{cs}{\newcommand{\cs}[1]{\texttt{\textbackslash{}#1}\relax}}%
12
13 % Define colors in case they are not available because style.tex was
14 % not loaded
15 % table colors
16 \colorlet{tablebodycolor}{white!100}
17 \colorlet{tablerowcolor}{gray!10}
18 \colorlet{tablesubheadcolor}{gray!30}
19 \colorlet{tableheadcolor}{gray!25}
20
21 \section{LaTeX Typesetting By Example}
22 \label{sec:example:tutorial}
23 This section demonstrates a basic set of LaTeX formatting commands and shows
24 how they look like in this template. For comparison of the typeset output with
25 the input document refer to the code listing starting on page \pageref{sec:
26 example:code}.
27
28 The content presented here is based on similar text by Phil Farrell\footnote{\
29 url{https://pangea.stanford.edu/computing/unix/formatting/latexexample.php}}
30 and Harvey Gould\footnote{\url{http://sip.clarku.edu/tutorials/TeX/}}.
31 For further reading on the possibilities of this template please refer to the
32 documentation: \path{TemplateDocumentation.pdf}.
33
34 % ~~~~~
35 \subsection{Plain Text}
36 \label{sec:example:PlainText}
37 \index{example!text}
38
39 Type your text in free-format; lines can be as long
40 or as short as you wish.
41
42     You can indent           or space out
43     your input
44     text in
45
46     any way you like to highlight the structure
47     of your manuscript and make it easier to edit.
48 LaTeX fills lines and adjusts spacing between words to produce an
49 aesthetically pleasing result.
50

```

```

43 Completely blank lines in the input file break your text into
44 paragraphs.
45 Several command exist to change the font for a single character, word, or set
46 of words. Simply enclose the word and within braces of the forming command,
47 \emph{like this}.
48 A font changing command not enclosed in braces, like the change to \bfseries
49 bold here, keeps that change in effect until the end of the document or
50 until countermanded by another font switch, like this change back to
51 \normalfont the default font.
52 % ~~~~~
53 \subsection{Font shapes}
54 \label{sec:example:FontShapes}
55 \index{example!font shapes}
56
57 The default font in the template is Latin Modern (lmodern). It includes \textit
58 {italics}, \textbf{boldface}, \textsl{slanted}, \textsc{small caps} and \texttt
59 {monospaced} fonts as well as the corresponding sans serif variants of the
60 same font family \textsf{sans serif}, \textsf{\textit{italics}}, \textsf{\textbf{boldface}}
61 and \textsf{\textsl{slanted}}. Note that for other fonts not
62 all font shapes may be available.
63 % ~~~~~
64 \subsection{Quotation and Citations}
65 \label{sec:example:QuoteCite}
66 \index{example!quote}
67 \index{example!cite}
68 %
69 LaTeX provides the \enquote{quote} and \enquote{quotation} environments for
70 typesetting quoted material or any other text that should be slightly indented
71 and set off from the normal text.
72
73 However, if the text shall not just be indented but rather be a real quotation
74 with a citation of the origin, then the commands \enquote{enquote} for inline
75 quotes and \enquote{blockquote} for multi line quotes are more appropriate. The
76 first is used to highlight the commands in this section and the latter in the
77 following text, which is a direct quotation from the documentation of the
78 package
79 \emph{csquotes}:
80 %
81 \blockquote[(csquotes.pdf)]{This command determines the length of the text.
82 If the length exceeds a certain threshold, the text will be
83 typeset in display mode, i. e., as a block quotation.
84 If not, \cs{blockquote} will behave like \cs{textquote}.
85 Depending on the threshold type option, the threshold may be based on the
86 number
87 of lines required to typeset the text or on the number of words in the text.}

```

```

78 The standard command for citations is \texttt{\textbackslash{}cite} which may
have a prenote argument for adding a page number or something similar. To show
how a citation is typeset we cite here a book about LaTeX \cite[59]{companion}.
Further commands such as \cs{parencite} \parencite{companion} and \cs{textcite}
\textcite{companion} allow a different typeset of the citation. The resulting
bibliography is printed out on \cpageref{sec:bibliography}. Refer to the
biblalex manual for further details on citation commands and modifications on
the printout and the section on biblalex in the template documentation.
79
80 % ~~~~~~
81 \subsection{References}
82 \label{sec:example:references}
83 \index{example!references}
84
85 So far, in this text chapter and section headings, paragraphs (\cref{sec:
example:PlainText}), font changes (\cref{sec:example:FontShapes}) and citations
(\cref{sec:example:QuoteCite}) were demonstrated ad in this section the use of
references. Not that here the command \texttt{\textbackslash{}cref} was used
instead of the standard \cs{ref}.
86
87 The following sections show lists, tables and math.
88
89 % ~~~~~~
90 \subsection{Lists}
91 \label{sec:example:lists}
92 \index{example!lists}
93 %
94 LaTeX has three types of lists with the environment names \emph{itemize}, \emph
{enumerate} and \emph{description}. All lists have a separation between each
item, to improve the reading of item texts spanning several lines.
95 This item text can contain multiple paragraphs. These paragraphs are
appropriately spaced and indented according to their position in the list.
96
97 \begin{itemize}
98 \item
99 The \enquote{itemize} sets off list items with \emph{bullets}, like this.
100 %
101 \item Of course, lists can be nested, each type up to at least four levels.
102 One type of list can be nested within another type.
103 %
104 \begin{itemize}
105 \item Nested lists of the same type will change style of numbering
106 or \emph{bullets} as needed.
107 \end{itemize}
108 \end{itemize}
109 %
110 \begin{enumerate}
111 \item The \enquote{enumerate} environment numbers the list elements.
112

```

```

113 This is a new paragraph in the item text, which is not intended as in the
114 normal text but separated from the previous paragraph.
115 %
116 \item The enumeration scheme changes with each nesting level
117   \begin{enumerate}
118   \item as shown in this nested enumerated list item.
119   \end{enumerate}
120 \end{enumerate}
121 %
122 Don't forget to close off all list environments with the
123 appropriate \verb+\end{...}+ command.
124 Indenting \verb+\begin{...}+, \verb+\item+, and \verb+\end{...}+
125 commands in the input document according to their nesting level can help
126 clarify the structure.
127
128 % ~~~~~
129 \subsection{Tables}
130 \label{sec:example:tables}
131 \index{example!tables}
132 %
133 Tables are a little more difficult. One can achieve even the most complex and
134 fancy layout, even spanning over multiple pages, but the code to create these
135 tables is not necessarily the best readable one.
136
137 Table \ref{tab:Computers} is a very simple table showing data lined up in
138 columns, where each column width is automatically calculated by LaTeX.
139 Notice that the tabular is centered with \cs{centering} and printed in a
140 smaller font to achieve a clear distinction to the normal text. The title is
141 created above the tabular with \cs{captionabove}.
142
143 \begin{table}[hb]
144   \centering
145   \small\renewcommand{\arraystretch}{1.4}
146   \captionabove{Numbers of Computers in the department, By Type.}
147   \label{tab:Computers}
148   \begin{tabular}{lr}
149     \hline
150     Mac (Apple)      & 2  \\
151     Windows XP, 7    & 60 \\
152     Linux (Server)  & 10 \\
153     \hline
154   \end{tabular}
155 \end{table}
156
157 \Cref{tab:IsingModel} on \cpageref{tab:IsingModel} demonstrate the creation of
158 a pleasant appearing table, which helps to read the table without attracting to
159 much attention by the use of shaded colors. The caption uses the additional
160 short caption in square brackets \texttt{[ ]}, which is used in the list of
161 tables, see \cpageref{sec:lot}.

```

```

153
154 \begin{table}[ht]
155 \centering
156 \small\renewcommand{\arraystretch}{1.4}
157 \rowcolors{1}{tablerowcolor}{tablebodycolor}
158 %
159 \captionabove[Mean-field predictions for the critical temperature of the Ising
model]{Comparison of the mean-field predictions for the critical temperature of
the Ising model with exact results and the best known estimates for different
spatial dimensions  $d$  and lattice symmetries.}
160 \label{tab:IsingModel}
161 %
162 \begin{tabularx}{0.5\textwidth}{lXXX}
163 \hline
164 \rowcolor{tableheadcolor}
165 lattice &  $d$  &  $q$  &  $T_{\text{mf}}/T_c$  \\
166 \hline
167 square & 2 & 4 & 1.763 \\
168 %
169 triangular & 2 & 6 & 1.648 \\
170 %
171 diamond & 3 & 4 & 1.479 \\
172 %
173 simple cubic & 3 & 6 & 1.330 \\
174 %
175 bcc & 3 & 8 & 1.260 \\
176 %
177 fcc & 3 & 12 & 1.225 \\
178 \hline
179 \end{tabularx}
180 \end{table}
181
182 The design and creating of complex tables is shown in much greater detail in
the documentation of this template.
183
184 % ~~~~~
185 \subsection{Mathematical Equations}
186 \label{sec:example:math}
187 \index{example!math}
188
189 Simple equations, like  $x^y$  or  $x_n = \sqrt{a + b}$  can be typeset right
190 in the text line by enclosing them in a pair of single dollar sign symbols.
191 Don't forget that if you want a real dollar sign in your text, like  $\$2000$ ,
192 you have to use the \verb+\$+ command.
193
194 A more complicated equation should be typeset in \emph{displayed math} mode
using \texttt{\textbackslash{}} ... \textbackslash{}}, like this:
195 %
196 \[

```

```

197 z \left( 1 \ +\ \sqrt{\omega_{i+1}} + \zeta - \frac{x+1}{\Theta + 1} y + 1\right)
198 \ \right)
199 \ \ \ =\ \ \ \ 1
200 \]
201 %
202 The \texttt{equation} environment displays your equations, and automatically
203 numbers them consecutively within your document, like this:
204 %
205 We can give an equation a label so that we can refer to it later.
206 \begin{equation}
207   \label{eqn:ising}
208   E = -J \sum_{i=1}^N s_i s_{i+1} ,
209 \end{equation}
210 Equation~\eqref{eqn:ising} expresses the energy of a configuration
211 of spins in the Ising model.\footnote{It is necessary to process (typeset) a
212 file twice to get the counters correct.}
213
214 For more complex formulas it may be necessary to do some fine tuning by adding
215 small amounts of horizontal spacing,
216 \begin{verbatim}
217   \, small space      \! negative space
218 \end{verbatim}
219 as is done in eq.~\eqref{eqn:GreenTheorem}.
220 \begin{equation}
221   \underset{\mathcal{G}}{\quad} \iiint \!
222   \left[ u \nabla^2 v + \left( \nabla u, \nabla v \right) \right] \mathrm{d}^3 V
223   = \underset{\mathcal{S}}{\quad} \oiint u, \frac{\partial v}{\partial n}
224   \,, \,, \mathrm{d}^2 A
225 \end{equation}
226 \label{eqn:GreenTheorem}
227 \end{equation}
228 We also can also align several equations
229 \begin{align}
230   \dot{q}_i &= \frac{\partial H}{\partial p_i} \ \ \
231   \dot{p}_i &= -\frac{\partial H}{\partial q_i}
232 \end{align}
233 number them as subequations
234 \begin{subequations}
235 \begin{align}
236   \dot{q}_i &= \frac{\partial H}{\partial p_i} \ \ \
237   \dot{p}_i &= -\frac{\partial H}{\partial q_i}
238 \end{align}
239 \end{subequations}
240 or with only a single number
241 \begin{equation}
242 \begin{aligned}
243   \dot{q}_i &= \frac{\partial H}{\partial p_i} \ \ \
244   \dot{p}_i &= -\frac{\partial H}{\partial q_i}
245 \end{aligned}
246 \end{equation}

```



```

245 Many further possibilities of displaying equations exist.
246
247 % ~~~~~
248 \subsubsection{Common Greek letters}
249 \label{sec:example:math:greekletters}
250 These commands may be used only in math mode. Only the most common
251 letters are included here.
252 %
253 \[\alpha, \beta, \gamma, \Gamma, \delta, \Delta,
254 \epsilon, \zeta, \eta, \theta, \Theta, \kappa,
255 \lambda, \Lambda, \mu, \nu, \xi, \Xi, \pi, \Pi,
256 \rho, \sigma, \tau, \phi, \Phi, \chi, \psi, \Psi,
257 \omega, \Omega\]
258
259 % ~~~~~
260 \subsection{Literal text}
261 \label{sec:example:verbatim}
262 \index{example!verbatim}
263 %
264 It is desirable to print program code exactly as it is typed in a
265 monospaced font. Use \cs{begin\{lstlisting\}} and
266 \cs{end\{lstlisting\}} as in the following example:
267
268 \begin{lstlisting}
269 double y0 = 10; // example of declaration and assignment statement
270 double v0 = 0;  // initial velocity
271 double t = 0;   // time
272 double dt = 0.01; // time step
273 double y = y0;
274 \end{lstlisting}
275 %
276 Two styles are defined in this template: \texttt{lstStyleCpp} and \texttt{lstStyleLaTeX}.
277
278 A complete file can be printed with listings using the
279 command \cs{lstinputlisting}, see \cref{sec:example:code} for an example.
280 % ~~~~~
281 \subsection{Figures}
282 \label{sec:example:figures}
283 \index{example!figures}
284 %
285 Figures with captions are included in the \texttt{figure} environment in order
to position the graphic inside the text. The size should be given in relation
to natural text size. It is recommended to use a percentage value of the \cs{
textwidth}. This size should not exceed 80\,\% of the text width.
286
287 \begin{figure}[htb]
288   \centering
289   \includegraphics[width=0.4\textwidth]{images/testimage.png}

```

```

290 \caption[Test image for television]{Test image for television (Origin of the
image: \url{http://de.wikipedia.org/wiki/Testbild}).}
291 \label{fig:example:figure}
292 \end{figure}
293
294 All possibilities of grouping pictures side by side, on top or in matrices can
be realized. Each subfigure is created in the same way as a graphic inside a
figure, just enclosed by a figure environment, as shown in \cref{fig:example:
subfigures}.
295
296 \begin{figure}[htb]
297 \begin{subfigure}[b]{.45\linewidth}
298 \centering
299 \includegraphics[width=0.5\linewidth]{images/testimage.png}
300 \caption{The first subfigure.}
301 \label{fig:example:subfigures:a}
302 \end{subfigure}%
303 \begin{subfigure}[b]{.45\linewidth}
304 \centering
305 \includegraphics[width=0.5\linewidth]{images/testimage.png}
306 \caption{The second subfigure.}
307 \label{fig:example:subfigures:b}
308 \end{subfigure}
309 \caption{Demonstration of the \emph{subfigure} environment inside a figure
environment}
310 \label{fig:example:subfigures}
311 \end{figure}
312 %
313 For complex subfigure constructs and correct alignment of the subcaption the \
texttt{floatrow} provides powerful commands.
314
315 % ~~~~~~
316 \subsection{Index}
317 \label{sec:example:index}
318 \index{example!index}
319 %
320 An index is easy to create with LaTeX, but should only be done if the time is
available to do it right, since it requires substantial work to create an index
which is really useful for the reader.
321
322 A word is added to the index with the command \cs{index\{word\}} and these
indexed words can be grouped with \cs{index\{group!word\}}. Within this
document some index commands are inserted below the section headers of this
tutorial for the purpose of demonstrating the indexing. The resulting index is
displayed on page~\pageref{sec:Index}.
323 % ~~~~~~
324 \clearpage
325 \subsection{Code}
326 \label{sec:example:code}

```

```
327  
328 \ifcsdef{lstStyleLaTeX}{%  
329   \lstinputlisting[style=lstStyleLaTeX,%nolol=true,%  
330     caption={LaTeX Typesetting By Example}, label=lstLaTeXExample]  
331     {content/template/latexutorial.tex}  
332 }{}
```

Listing 3.1: LaTeX Typesetting By Example

CHAPTER 4

Results

CHAPTER 5

Summery and Outlook

List of Figures

List of Tables

Listings

A First chapter of appendix

A.1 Parameters

Publications

Scientific publications

Submissions to international conferences

Submissions to national conferences

Curriculum Vitae

Delete these notes:

This is a modified version of a german CV. I have not translated it into English, because I am not familiar with English CV styles.

Remember that you do not write this CV to apply for a job. This is just a brief summary of your previous research career. A 'real' CV is much more complex!

Personalien

Name	Max Musterman geboren am 01.02.1979 in Berlin ledig, deutsch
------	--

Schulbildung

1998	Abitur, Gymnasium Musterschule in Berlin
------	--

Zivildienst

07/98 - 08/99	<Einfügen>
---------------	------------

Studium

SS/99 - SS/06	Universität Hannover, Studium der Physik Thema der Diplomarbeit: 'Charakterisierung des Rauschverhaltens eines weit abstimmbaren Ytterbium dotierten kerngepumpten Faserlasers', durchgeführt am Laserzentrum Hannover e. V.
Mai 2006	Abschluss: Diplom-Physiker

Promotion

09/2006 - heute	Wissenschaftlicher Mitarbeiter am Institut für Quantenoptik, Leibniz Universität Hannover
-----------------	---

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