Institute of Architecture of Application Systems

University of Stuttgart
Universitätsstraße 38
D–70569 Stuttgart

Masterarbeit

Energy and CO2 footprint of cloud/backend processing

Erisa Hoxha

Course of Study:	Computer Science
Examiner:	Prof. Dr. Marco Aiello
Supervisor:	Prof. Dr. Marco Aiello
Commenced:	November 22, 2023
Completed:	May 22, 2024

Abstract

<Short summary of the thesis>

Contents

List of Figures

List of Tables

List of Listings

List of Algorithms

Acronyms

ER error rate. 44

FR Fehlerrate. 44

RDBMS Relational Database Management System. 44

1 Introduction

This thesis starts with Chapter 2.

We can also typeset `<text>verbatim text</text>`. Backticks are also rendered correctly: `` `words in backticks` ``.

2 Chapter Two

LaTeX hints are provided in Appendix A.

3 Heading on Level 0 (chapter)

Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. $\sin^2(\alpha) + \cos^2(\beta) = 1$. If you read this text, you will get no information $E = mc^2$. Really? Is there no information? Is there a difference between this text and some nonsense like "Huardest gefburn"? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$. This text should contain all letters of the alphabet and it should be written in of the original language. $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \sqrt[n]{\frac{a}{b}}$. There is no need for special content, but the length of words should match the language. $a\sqrt[n]{b} = \sqrt[n]{a^n b}$.

3.1 Heading on Level 1 (section)

Hello, here is some text without a meaning. $\mathrm{d}\Omega = \sin\vartheta \mathrm{d}\vartheta \mathrm{d}\varphi$. This text should show what a printed text will look like at this place. If you read this text, you will get no information. Really? Is there no information? Is there a difference between this text and some nonsense like "Huardest gefburn"? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. $\sin^2(\alpha) + \cos^2(\beta) = 1$. This text should contain all letters of the alphabet and it should be written in of the original language $E = mc^2$. There is no need for special content, but the length of words should match the language. $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$.

3.1.1 Heading on Level 2 (subsection)

Hello, here is some text without a meaning. $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \sqrt[n]{\frac{a}{b}}$. This text should show what a printed text will look like at this place. $a\sqrt[n]{b} = \sqrt[n]{a^n b}$. If you read this text, you will get no information. $\mathrm{d}\Omega = \sin\vartheta \mathrm{d}\vartheta \mathrm{d}\varphi$. Really? Is there no information? Is there a difference between this text and some nonsense like "Huardest gefburn"? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. This text should contain all letters of the alphabet and it should be written in of the original language. There is no need for special content, but the length of words should match the language. $\sin^2(\alpha) + \cos^2(\beta) = 1$.

Heading on Level 3 (subsubsection)

Hello, here is some text without a meaning $E = mc^2$. This text should show what a printed text will look like at this place. $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$. If you read this text, you will get no information. $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \sqrt[n]{\frac{a}{b}}$. Really? Is there no information? Is there a difference between this text and some nonsense like "Huardest gefburn"? Kjift – not at all! A blind text like this gives you information

about the selected font, how the letters are written and an impression of the look. $a\sqrt[n]{b} = \sqrt[n]{a^n b}$. This text should contain all letters of the alphabet and it should be written in of the original language. $\mathrm{d}\Omega = \sin\vartheta \mathrm{d}\vartheta \mathrm{d}\varphi$. There is no need for special content, but the length of words should match the language.

Heading on Level 4 (paragraph) Hello, here is some text without a meaning. This text should show what a printed text will look like at this place. $\sin^2(\alpha) + \cos^2(\beta) = 1$. If you read this text, you will get no information $E = mc^2$. Really? Is there no information? Is there a difference between this text and some nonsense like "Huardest gefburn"? Kjift – not at all! A blind text like this gives you information about the selected font, how the letters are written and an impression of the look. $\sqrt[n]{a} \cdot \sqrt[n]{b} = \sqrt[n]{ab}$. This text should contain all letters of the alphabet and it should be written in of the original language. $\frac{\sqrt[n]{a}}{\sqrt[n]{b}} = \sqrt[n]{\frac{a}{b}}$. There is no need for special content, but the length of words should match the language. $a\sqrt[n]{b} = \sqrt[n]{a^n b}$.

3.2 Lists

3.2.1 Example for list (itemize)

- First item in a list
- Second item in a list
- Third item in a list
- Fourth item in a list
- Fifth item in a list

Example for list (4*itemize)

- First item in a list
  - First item in a list
    - First item in a list
      - First item in a list
      - Second item in a list
    - Second item in a list
  - Second item in a list
- Second item in a list

3.2.2 Example for list (enumerate)

1. First item in a list
2. Second item in a list
3. Third item in a list
4. Fourth item in a list
5. Fifth item in a list

Example for list (4*enumerate)

1. First item in a list
    a) First item in a list
        i. First item in a list
            A. First item in a list
            B. Second item in a list
        ii. Second item in a list
    b) Second item in a list
2. Second item in a list

3.2.3 Example for list (description)

First item in a list

Second item in a list

Third item in a list

Fourth item in a list

Fifth item in a list

Example for list (4*description)

First item in a list

First item in a list

First item in a list

First item in a list

Second item in a list

Second item in a list

Second item in a list

Second item in a list

4 Related Work

Describe relevant scientific literature related to your work.

5 Conclusion and Outlook

Outlook

Bibliography

[ASF16] The Apache Software Foundation. *Apache ODE™ – The Orchestration Director Engine*. 2016. URL: http://ode.apache.org (cit. on p. 32).

[RVA16] H. Reijers, I. Vanderfeesten, W. van der Aalst. "The effectiveness of workflow management systems: A longitudinal study". In: *International Journal of Information Management* 36.1 (Feb. 2016), pp. 126–141. DOI: 10.1016/j.ijinfomgt.2015.08.003 (cit. on p. 32).

[WCL+05] S. Weerawarana, F. Curbera, F. Leymann, T. Storey, D. F. Ferguson. *Web Services Platform Architecture : SOAP, WSDL, WS-Policy, WS-Addressing, WS-BPEL, WS-Reliable Messaging, and More*. Prentice Hall PTR, 2005. ISBN: 0131488740. DOI: 10.1.1/jpb001 (cit. on p. 31).

All links were last followed on March 17, 2018.

A LaTeX Hints

> We cannot solve our problems with the same level of thinking that created them
>
> *(Albert Einstein)*

One sentence per line. This rule is important for the usage of version control systems. A new line is generated with a blank line. As you would do in Word: New paragraphs are generated by pressing enter. In LaTeX, this does not lead to a new paragraph as LaTeX joins subsequent lines. In case you want a new paragraph, just press enter twice (!). This leads to an empty line. In word, there is the functionality to press shift and enter. This leads to a hard line break. The text starts at the beginning of a new line. In LaTeX, you can do that by using two backslashes (\\). This is rarely used.

Please do *not* use two backslashes for new paragraphs. For instance, this sentence belongs to the same paragraph, whereas the last one started a new one. A long motivation for that is provided at http://loopspace.mathforge.org/HowDidIDoThat/TeX/VCS/#section.3.

One can write *emphasized text (rendered in italics)* and **bold text**.

A.1 File Encoding and Support of Umlauts

The template offers foll UTF-8 support. All recent editors should not have issues with that.

A.2 Citations

References are set by means of `\cite[key]`.

Code:

```
Example: \cite{WSPA} or by author input: \
citet{WSPA}.
```

Result:

Example: [WCL+05] or by author input: Weerawarana et al. [WCL+05].

The following sentence demonstrates 1. the capitalization of author names at the beginning of the sentence, 2. the correct citation using author names and the reference, 3. that the author names are a hyperlink to the bibliography and that 4. the bibliography contains the name prefix “van der” of “Wil M. P. van der Aalst”.

Code:

```
\Citet{RVvdA2016} present a study on the
effectiveness of workflow management systems.
```

Result:

Reijers et al. [RVA16] present a study on the effectiveness of workflow management systems.

The following sentence demonstrates that you can overwrite the text part of the generated label using `label` in a bibliopgrahie-entry, but the year and the uniqueness are still generated by biber.

Code:

```
The workflow engine Apache ODE \cite{
ApacheODE} executes \BPEL processes reliably.
```

Result:

The workflow engine Apache ODE [ASF16] executes BPEL processes reliably.

Code:

```
Words are best enclosed using \texttt{\
textbackslash qq\{..\}}, then the correct
quotes are used.
```

Result:

Words are best enclosed using \qq{..}, then the correct quotes are used.

When creating the Bibtex file it is recommended to make sure that the DOI is listed.

A.3 Formulas and Equations

Code:

```
Equations $f(x)=x$ inside the text can be
provided.
```

Result:

Equations $f(x) = x$ inside the text can be provided.

A list with all available mathematical symbols is provided at http://texdoc.net/pkg/symbols-a4.

Code:

```
As an example, the set of natural numbers is
given by $\mathbb{N}$.
```

Result:

As an example, the set of natural numbers is given by $\mathbb{N}$.

Listing A.1 The code is separated by two horizontal lines in the listings environment.

```
<listing name="second sample">
  <content>not interesting</content>
</listing>
```

For the documentation of editing mathematical formulas read the package documentation of `amsmath`[1].

Equation A.1 is numbered and can be referenced in the text:

Code:

```
\begin{align}
  \label{eq:test}
  x = y
\end{align}
```

Result:

$$x = y \tag{A.1}$$

The following equation is not numbered because of using `\align*` as environment.

Code:

```
\begin{align*}
  x = y
\end{align*}
```

Result:

$$x = y$$

The template offers `\abs` to enable the bars to scale well at the absolute value:

Code:

```
$\abs{X}$.
```

Result:

$|X|$.

The documentation available at http://www.ctan.org/tex-archive/help/Catalogue/entries/voss-mathmode.html provides more details about mathematical environments.

A.4 Sourcecode

Listing A.1 shows how to embed source code. With `\lstinputlisting` the source code can be loaded directly from files.

[1] http://texdoc.net/pkg/amsmath

Algorithm A.1 Sample algorithm

procedure SAMPLE(a,v_e)
  parentHandled $\leftarrow$ $(a = \text{process}) \vee \text{visited}(a'), (a', c, a) \in \text{HR}$
    // $(a', c'a) \in \text{HR}$ denotes that a' is the parent of a
  if parentHandled $\wedge$ $(\mathcal{L}_{in}(a) = \emptyset \vee \forall l \in \mathcal{L}_{in}(a) : \text{visited}(l))$ **then**
    visited(a) $\leftarrow$ true
    $$\text{writes}_\circ(a, v_e) \leftarrow \begin{cases} \text{joinLinks}(a, v_e) & |\mathcal{L}_{in}(a)| > 0 \\ \text{writes}_\circ(p, v_e) & \exists p : (p, c, a) \in \text{HR} \\ (\emptyset, \emptyset, \emptyset, false) & \text{otherwise} \end{cases}$$
    if $a \in \mathcal{A}_{basic}$ **then**
      HANDLEBASICACTIVITY(a,v_e)
    else if $a \in \mathcal{A}_{flow}$ **then**
      HANDLEFLOW(a,v_e)
    else if a = process **then** // Directly handle the contained activity
      HANDLEACTIVITY(a',v_e), $(a, \perp, a') \in \text{HR}$
      $\text{writes}_\bullet(a) \leftarrow \text{writes}_\bullet(a')$
    end if
    for all $l \in \mathcal{L}_{out}(a)$ **do**
      HANDLELINK(l,v_e)
    end for
  end if
end procedure

Code:

```
Source code is also available in the text \
lstinline|<listing />|.
```

Result:

Source code is also available in the text `<listing />`.

A.5 Pseudocode

Algorithm A.1 shows a sample algorithm.

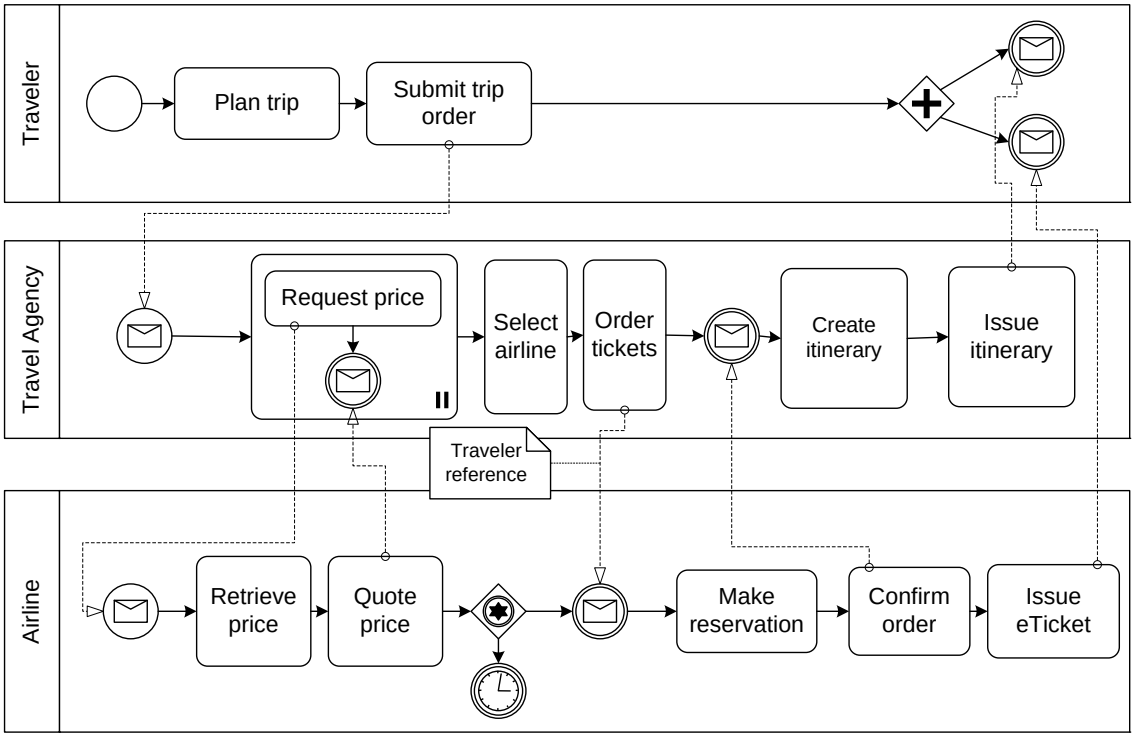


Figure A.1: Example Choreography

And if you want to write an algorithm that goes over several pages, you can only do this with the following **dirty** hack:

Algorithmus A.2 Description

code goes here
test2

A.6 Figures

The Figure A.1 and A.2 are important to understand this document. In the appendix Figure A.4 on page 37 shows again the complete choreography.

Figure A.3 shows the usage of the package subcaption. It is indeed possible to reference to sub figures: Figure A.3a.

It is possible to convert SVGs to PDF directly during compilation. This is described in the source code of latex-tipps.tex, but commented out.

A.7 More Illustrations

Figures A.4 and A.5 show two choreographies, which should further explain the facts. The second figure is rotated 90 degrees to demonstrate the `pdflscape` package.

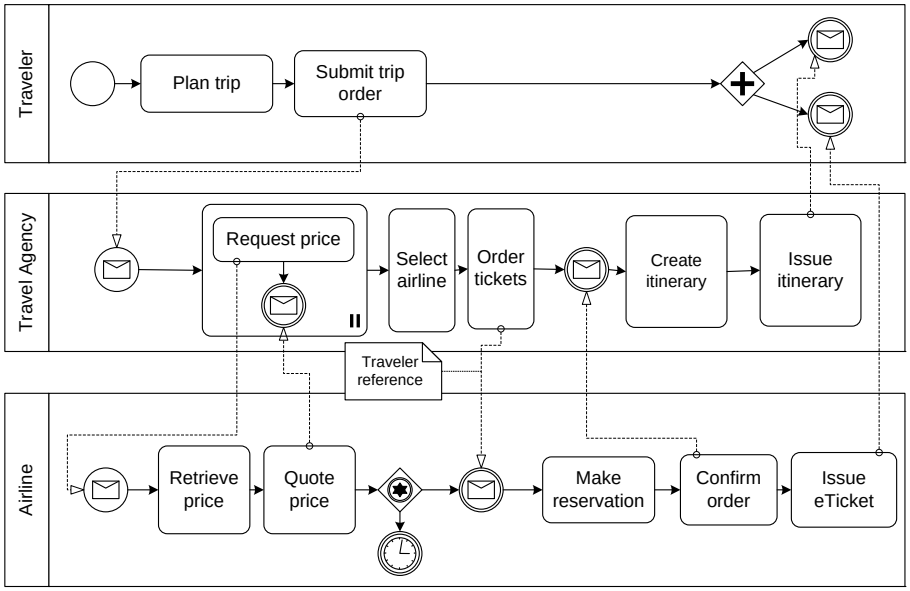
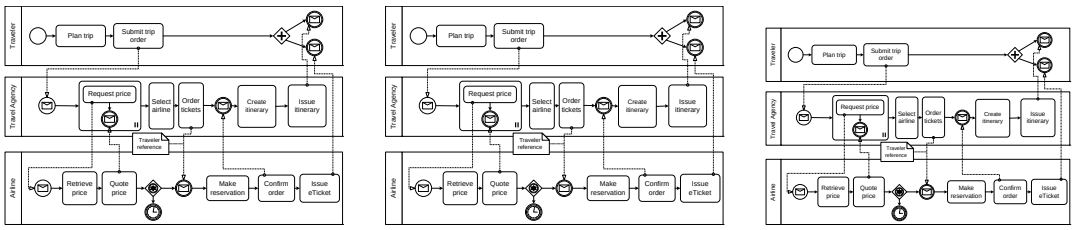


Figure A.2: The example choreography. Now slightly smaller to demonstrate `\textwidth`. And also the use of alternative captions for the list of images. However, the latter is only conditionally recommended, because who reads so much text under a picture? Or is it just a matter of style?



(a) Choreography 1 **(b)** Choreography 2 **(c)** Choreography 3

Figure A.3: Example to place 3 illustrations next to each other. Further, it is possible to reference each separately.

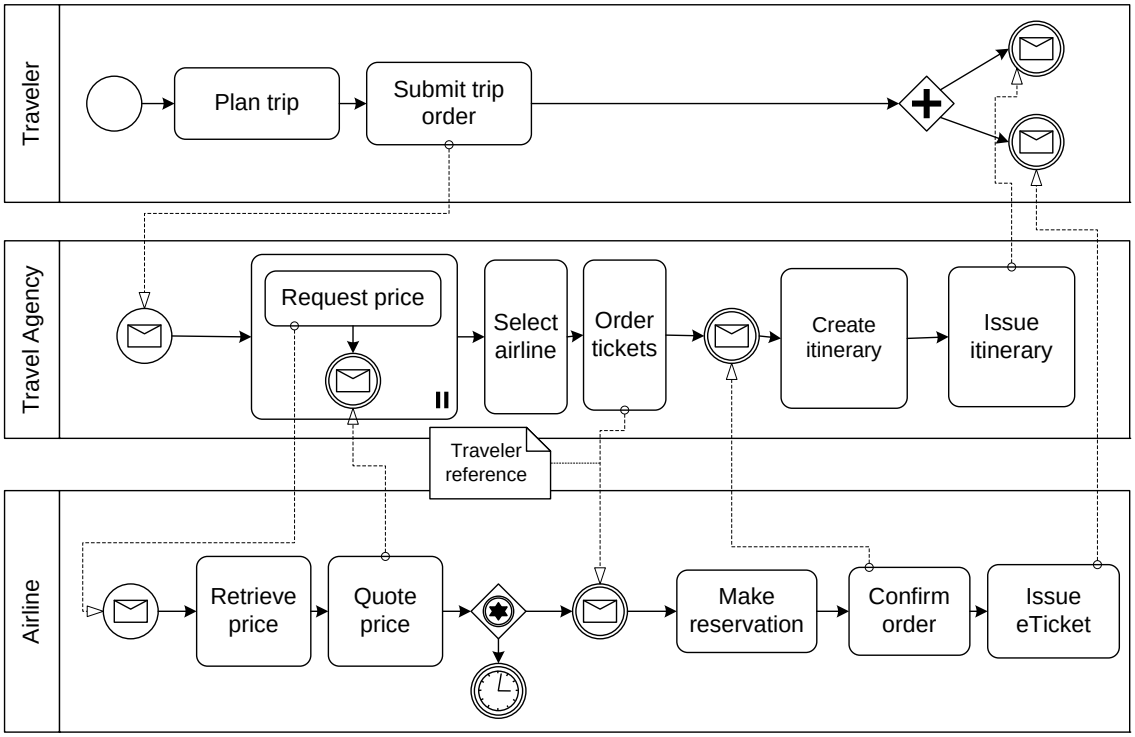


Figure A.4: Example Choreography I

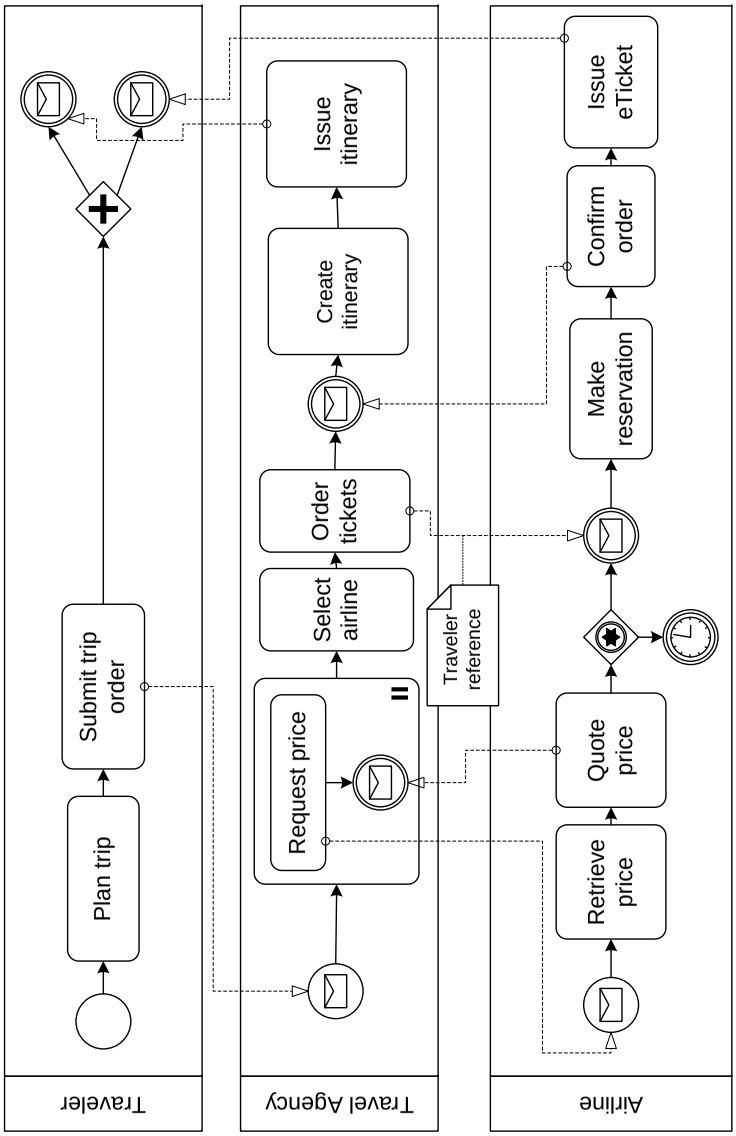


Figure A.5: Example Choreography II

A.8 Plots with pgfplots

The package pdfplots provides plotting of functions directly in LaTeX like with matlab or gnuplot. Some visual examples are available here[2].

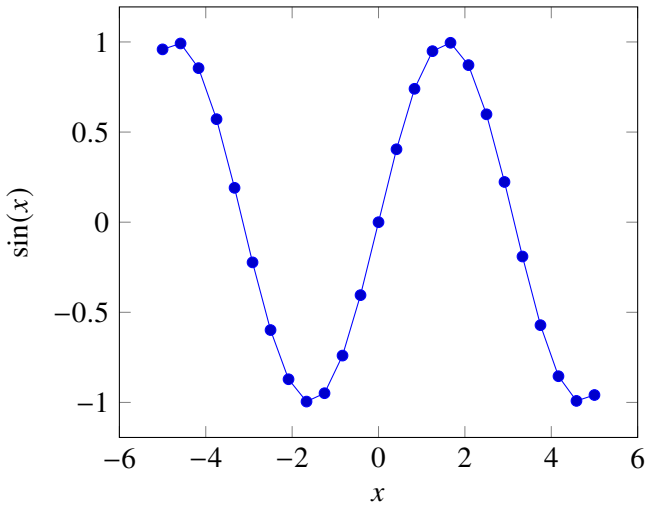


Figure A.6: Plot of $\sin(x)$ direclty inside the figure environment with pgfplots.

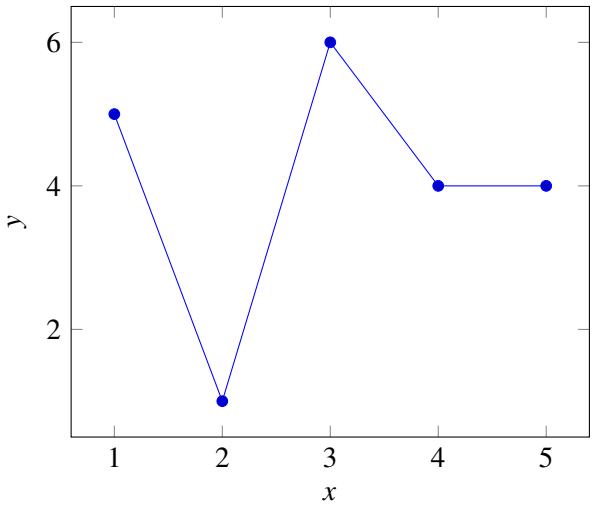


Figure A.7: Coordinates x and y read from csv file and plotted pgfplots.

A.9 Figures with tikz

The tikz is a package for creating graphics programmatically. With this package grids or other regular strucutres can be easliy generated.

[2] http://texdoc.net/pkg/visualtikz

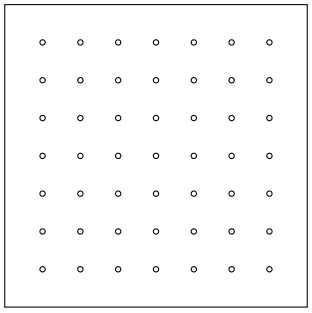


Figure A.8: A regular grid generated easily with two for loops.

A.10 UML diagrams using tikz-uml

Figure A.9 presents a class diagram typeset using tikz-uml.

A.11 UML diagrams using PlantUML

In case LuaLaTeX is used and PlantUML is installed, UML diagrams can be defined using PlantUML.

A.12 Linguistic Forests

Code:

```
\begin{forest}
  [VP
    [DP]
    [V
      [V]
      [DP]
    ]
  ]
\end{forest}
```

Result:

A.13 Tables

Table A.1 shows results and Table A.2 shows how numerical data can be represented in a table.

A.13.1 Tables with pgfplots

With the pgfplotstable package tables can be directly generated from a csv file.

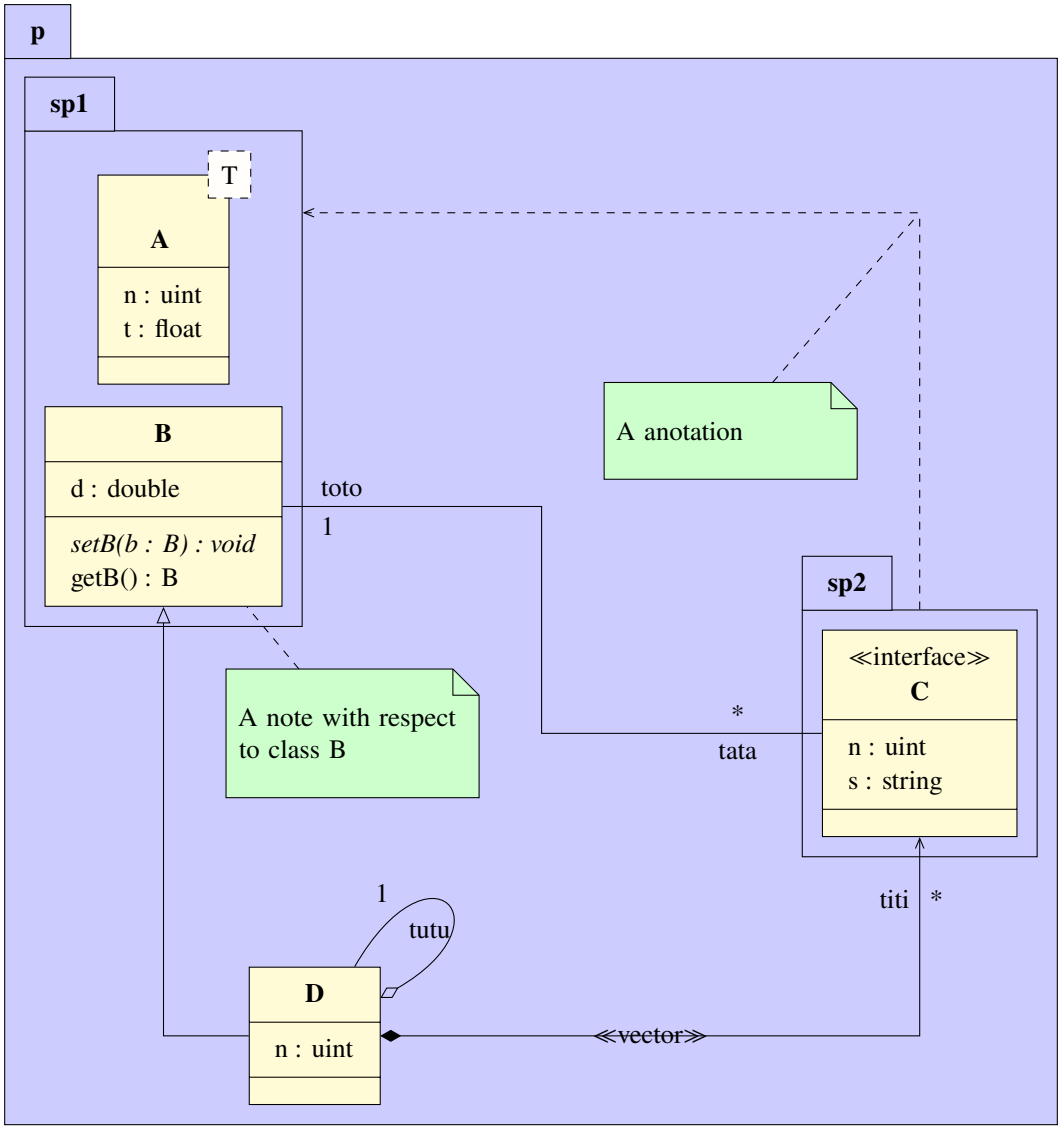


Figure A.9: Class diagram generated with tikz-uml. Example adapted from Nicolas Kielbasiewicz.

summed		Title
Table	as	in
tabsatz.pdf	recommended	gesetzt
Example	a nice example for using “multirow”	

Table A.1: Exampe Table – see http://www.ctan.org/tex-archive/info/german/tabsatz/

	Parameter 1		Parameter 2		Parameter 3		Parameter 4	
Bedingungen	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
W	1.1	5.55	6.66	.01				
X	22.22	0.0	77.5	.1				
Y	333.3	.1	11.11	.05				
Z	4444.44	77.77	14.06	.3				

Table A.2: Example table for 4 constraints (W-Z), each having 4 parameters with (M und SD). Note: use always the same number of decimal places.

	b	c	d
1	4	5	1
2	3	1	5
3	5	6	1
4	1	4	9
5	3	4	7

Table A.3: Table directly generated from the values of a csf file.

A.14 Tables spanning multiple pages

Table A.4: A sample long table.

First column	Second column	Third column
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
Continued on next page		

Table A.4 – continued from previous page

First column	Second column	Third column
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D

Continued on next page

Table A.4 – continued from previous page

First column	Second column	Third column
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D
A	BC	D

A.15 Abbreviations

At the first pass, the Fehlerrate (FR) was 5. At the second pass was FR 3. The plural form can be seen here: error rates (ERs). To demonstrate what the list of abbreviations looks like for longer description texts, Relational Database Management Systems (RDBMS) must be mentioned here.

With `\gls{...}` you can enter abbreviations, the first time you call it, the long form is used. When reusing `\gls{..}` the short form is automatically displayed. The abbreviation is also automatically inserted in the abbreviation list. With `\glspl{...}` the plural form is used. If you want the short form to appear directly at the first use, you can use `\glsunset{..}` to mark an abbreviation as already used. The opposite is achieved with `\glsreset{..}`.

Abbreviations are defined in `\content\ausarbeitung.tex` by means of `\newacronym{...}{...}{...}`.

More information at: http://tug.ctan.org/macros/latex/contrib/glossaries/glossariesbegin.pdf

A.16 References

For distant sections "varioref" is recommended: "See Appendix A.3 on page 32". The command `\vref` works similarly to `\cref` the difference being that a reference to the page is additionally added. `vref`: "Appendix A.1 on page 31", `cref`: "Appendix A.1", `ref`: "A.1".

If "varioref" causes difficulties, then "cref" can be used instead. This also creates the word "section" automatically: Appendix A.3. This is also possible for illustrations etc. In English please use `\Cref{...}` (with large "C" at the beginning).

A.17 Definitions

Definition A.17.1 (Title)
Definition Text

Definition A.17.1 shows . . .

A.18 Footnotes

Footnotes are provided by the command `\footnote{...}`[3]. Citing footnotes is possible by provinding a label`\footnote{\label{...}...}` and cite the footnote with `\cref{...}` in the text[3].

A.19 Various Things

Code:

```
\begin{compactenum}[I.]
  \item You can also keep the numbering
compact thanks to paralist
  \item and switch to a different numbering
\end{compactenum}
```

Result:

I. You can also keep the numbering compact thanks to paralist
II. and switch to a different numbering

[3] Example footnote.

The words “workflow” and “dwarflike” can be copied from the PDF and pasted to a text file.

Code:

```
In case \LuaLaTeX{} is used as the compiler,
there is no ligature at \qq{f\/l} in the word
 \qq{dwarflike} (in contrast to \qq{fl} at \
qq{workflow}).
In other words: \qq{dwarflike} and \qq{dwarf
\/like} look the same in the PDF.
In case they do not, there is an issue with
Lua\LaTeX{} and the selnolig package.
```

Result:

In case LuaLaTeX is used as the compiler, there is no ligature at “fl” in the word “dwarflike” (in contrast to “fl” at “workflow”). In other words: “dwarflike” and “dwarflike” look the same in the PDF. In case they do not, there is an issue with LuaLaTeX and the selnolig package.

A.20 Closing remarks

Please feel free to provide enhancements for this template and create a new ticket on GitHub (https://github.com/latextemplates/uni-stuttgart-computer-science-template/issues).

Declaration

I hereby declare that the work presented in this thesis is entirely my own and that I did not use any other sources and references than the listed ones. I have marked all direct or indirect statements from other sources contained therein as quotations. Neither this work nor significant parts of it were part of another examination procedure. I have not published this work in whole or in part before. The electronic copy is consistent with all submitted copies.

---

place, date, signature