TECHNISCHE UNIVERSITÄT DRESDEN

Computer Graphics and Visualization

Faculty of Computer Science

Institute of Software and Multimedia Technology
Chair of Computer Graphics and Visualization

Bachelor Thesis

Occlusion Avoidance for Immersive Inspection of 3D Cell Complexes and Cell Surfaces

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Born on: 6th January 2001 in Dresden
Matriculation number: 4901060

31st October 2022

First referee
Prof. Dr. Stefan Gumhold

Second referee
2nd Referee

Supervisor
Supervisor I

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Faculty of Computer Science Chair of Computer Graphics and Visualization

Task for the preparation of a Bachelor Thesis

Course:	Computer Science
Name:	Joris Grau
Matriculation number:	4901060
Matriculation year:	2020
Title:	Occlusion Avoidance for Immersive Inspection of 3D Cell Complexes and Cell Surfaces

Objectives of work

Momentan ist das besagte Thema in aller Munde. Insbesondere wird es gerade in vielen – wenn nicht sogar in allen – Medien diskutiert. Es ist momentan noch nicht abzusehen, ob und wann sich diese Situation ändert. Eine kurzfristige Verlagerung aus dem Fokus der Öffentlichkeit wird nicht erwartet. Als Ziel dieser Arbeit soll identifiziert werden, warum das Thema gerade so omnipräsent ist und wie dieser Effekt abgeschwächt werden könnte. Zusätzlich sind Methoden zu entwickeln, mit denen sich ein ähnlicher Vorgang zukünftig vermeiden lässt.

Focus of work

- Recherche & Analyse
- Entwicklung eines Konzeptes & Anwendung der entwickelten Methodik
- Dokumentation und grafische Aufbereitung der Ergebnisse

First referee:	Prof. Dr. Stefan Gumhold
Second referee:	2nd Referee
Supervisor:	Supervisor I
Issued on:	1st April 2015
Due date for submission:	1st October 2015

Prof. Dr. Stefan Gumhold
Supervising professor

Statement of authorship

I hereby certify that I have authored this document entitled *Occlusion Avoidance for Immersive Inspection of 3D Cell Complexes and Cell Surfaces* independently and without undue assistance from third parties. No other than the resources and references indicated in this document have been used. I have marked both literal and accordingly adopted quotations as such. There were no additional persons involved in the intellectual preparation of the present document. I am aware that violations of this declaration may lead to subsequent withdrawal of the academic degree.

Dresden, 31st October 2022

Joris Grau

Abstract

This is an abstract. The abstract is written after finishing the work and should give an overview about the motivation, used methods, as well as the results. It is here to inform the reader about the core topics of the work and if it is relevant to his research. The abstract stands for itself and uses no components of the rest of the work. In consequence, there are no references nor citations used here. It should be around 100 to 250 words. There should always be an english version of your abstract, regardless of the language the work is actually written in.

Zusammenfassung

Das ist eine Zusammenfassung. Die Zusammenfassung wird geschrieben, nachdem die Arbeit ferttiggestellt ist und sollte einen Überblick über Motivation, Methoden und die Ergebnisse geben. Die Zusammenfassung informiert den Leser über die Kernthemen der Arbeit und ob die Arbeit für seine Forschung relevant ist. Die Zusammenfassung ist von der Arbeit entkoppelt und verwendet keine anderen Komponenten der Arbeit. In der Folge werden hier keine Referenzen oder Zitierungen genutzt. Sie sollte zwischen 100 und 250 Worten umfassen. Unabhängig von der Sprache, in der die Arbeit verfasst wurde, sollte es immer eine englische Version der Zusammenfassung geben.

Contents

Symbols and Acronyms

WYSIWYG	What You See Is What You Get
CGV lab	Chair of Computer Graphics and Visualization
GPU	Graphics Processing Unit

0 About Latex and this Template

This is the official template for the chair of computer graphics and visualization. It is based on the TU corporate design, more exactly on the `tudscrbook` class, which is a wrapper for the `scrbook` Koma script. The documentation[1] of the wrapper class might be useful, if there are things you need to understand and are not covered in this short description.

0.1 Using the Template

This template comes with a few files. This section will guide you through their structure, but will also explain, how to switch languages and how to change the type of your work.

0.1.1 File Structure

The multiple files of this template contain the different parts of the work. They are all brought together by the `main.tex` file, which solely purpose is, to connect all the files as the *root document*. When you are using Texmaker or TeXStudio to edit and compile these files, you should apply the option to make this file the *root document*.

All other text files are contained within four folders:

- **0_frontmatter:** Contains all files that are technically needed to define the documents properties and formal pages such as the *"Statement of Authorship* as well, as all other parts of the work, which are placed before the actual chapters of the work.
- **1_mainmatter:** Contains the chapters of the work
- **2_bib:** Contains the bib-file, as well as a tex file to print the bibliography within the document. It is possible to use multiple bib-files, just make sure every file is added in the *header* with `\addbibresource{path to file}`.
- **3_appendix:** Contains any appendix files, in the template, there is only an example file with some blind text.

There are two additional folders:

[1] https://ftp.tu-chemnitz.de/pub/tex/macros/latex/contrib/tudscr/doc/tudscr.pdf

- **fig:** For image files.
- **logo:** Containing the logos of the chair.

Within the frontmatter-directory, there are the following files:

- **0_header:** Containing the definition of the used class, as well as most parameters and used packages.
- **1_title:** Defines the information used for creating the title. It is also used to define some pdf meta data. The subject of the work is also defined in this file. All possible subjects can be found in the documentation.
- **2_task:** A file used to include the task description.
- **3_declaration:** Adds the statement of authorship.
- **4_abstract:** Side containing an English and a German abstract.
- **5_acronyms:** The place to declare your used acronyms.

0.1.2 Changing the Language to German

The standard language for this template is English. However, everything needed for changing the language to German is already in the template. To do this, enter the `0_frontmatter/0_header.tex` file and search the first few lines of the document for `ngerman, english`, in the `documentclass` options. Then swap the order to `english, ngerman,`. You still have to translate some of the text, but most things should change into German automatically.

0.1.3 Biblatex and Biber

This template uses `biblatex` and `biber` for creating a bibliography. However, most editors use the older `bibtex` as a standard[2]. To change this in TeXStudio or Texmaker, just enter Options -> Configure TeXStudio/Texmaker -> Build and change the default bibliography tool from bibtex to Biber. You can also just change the bibliography back to bibtex in the *0_frontmatter/0_header.tex* file by replacing the `backend=biber` option for the `biblatex` package back to `bibtex`. Most scientific resources allow to export a bibtex-citation directly, which can be copied to the bib file and used with the `\cite{<identifier>}` command. The result should look like this: [Foley1982].

0.1.4 Adapt the Template to Different Types of Works

When writing a diploma, bachelor's or master's thesis, there is little to change in this template. The `\subject`-field in the title page, see Table 1 for possible values, and the `\graduation[<short form>]<degree>`-field in the `0_frontmatter/1_title.tex` need to be adjusted. For other works, the task-description and declaration of independence should be removed by deleting the lines referencing the files `2_task.tex` and `3_declaration.tex` in the `main.tex` file, the list of figures and the list of tables could also be removed there. When the work is never intended to be printed, it might also be a consideration to change some of

[2] A discussion of the differences of both bibliography tools and the problems one or the other may cause can be found here: https://tex.stackexchange.com/questions/25701/

Table 1: All possible types of work.

Value	German	English
diss	Dissertation	Dissertation
doctoral	Dissertation	Dissertation
phd	Dissertation	Dissertation
diploma	Diplomarbeit	Diploma Thesis
master	Master-Arbeit	Master Thesis
bachelor	Bachelor-Arbeit	Bachelor Thesis
student	Studienarbeit	Student Thesis
evidence	Großer Beleg	Student Research Project
project	Projektarbeit	Project Paper
seminar	Seminararbeit	Seminar Paper
term	Hausarbeit	Term Paper
research	Forschungsbericht	Research Report
log	Protokoll	Log
report	Bericht	Report
internship	Praktikumsbericht	Internship Report

the options for the `\documentclass` in the `0_frontmatter/0_header.tex`. Expecially there is no need for additional space at the inside, so the `bcor`-parameter, used to compensate the print area in respect to the book thickness when printed, can be set to zero or removed completely and the `twoside`-parameter with the following outside paging might be irritating and can be changed to `oneside`.

0.2 Latex Basics

The following sections will explain some of the Latex basics. It is especially concerned with figures (0.2.2), acronyms (0.2.3), equations (0.2.4), tables (0.2.5) and code listings (0.2.6). If you already worked with Latex, there is probably no need to read this, but if you never used Latex or are stumbling over some of the elements in this template, it might be useful. It shows also some of the notations used at the Chair of Computer Graphics and Visualization (CGV lab), so looking in the source code of this file (`1_mainmatter/0_about_this_template.tex`) might be useful.

0.2.1 Weblinks

For Weblinks there are two ways to include them into a latex document. You can just use the `\url{<url>}` command or use `\href{<url>}{<text>}`. While an example link with the `url` command would look like https://wwwpub.zih.tu-dresden.de/~gumhold/cgv/html/overview.html, href is probably a more elegant solution, where the link to the cgv framework on

pub.zih.tu-dresden.de can be embedded into the text. However, as long as the link color is black (which it should be for printed formats), the link is hard to find and in a printed format, the information about the link is lost entirely, if it is not contained within the text. So writing down at least a part of the link can help with recognizing the link as a link. Links should not be placed in the text, but rather in footnotes using the `\footnote{footnote}`-command.

0.2.2 Figures

You can embed figures with the commands shown in figure 1. The result for an example should look like figure 2. Figure objects are useful to include graphics, but can also host a range of other elements. The most important property of figures is, that they are floating objects, which latex is trying to place where they fit best.

```
\begin{figure}[ht]              % [h] tries to keep the figure [h]ere, [t]op is used as alternative
        \centering              % center the graphic, if it is smaller then the page
        \includegraphics[width=<scaling factor>\textwidth]{<path to the graphic>}
        \caption{<The text to describe the graphic.>}
        \label{<A label to refer to the graphic in the text.>}
\end{figure}
```

Figure 1: Code for embedding graphics

Figure 2: Quadric error metric simplification applied to the Stanford bunny

0.2.3 Symbols and Acronyms

This template uses the *acronyms*-package to include a list of symbols and acronyms at the beginning of the work. Acronyms can be referenced with the `\ac{<identifier>}` command. E.g. using `\ac{GPU}` in this document results in: Graphics Processing Unit (GPU), the name of the acronym or symbol, as well as the acronym or symbol itself in brackets. After the first use, only the acronym or symbol will be used. The `acronyms`-package will throw a warning if an acronym is not used within the work.

0.2.4 Equations

Equations can be used with the math environment, which can be delimited either inline by using the `$ eq $`, `\[ eq \]`, or separated from the text with `\begin{equation} eq`

`\end{equation}`. The latter will additionally enumerate the equation and allows for a label, so we can reference an equation like the equation 0.1.

$$x^n + y^n = z^n \tag{0.1}$$

You can also place equations within a figure. The equation then becomes a floating object and might be placed somewhere else, but can also be captioned, as equation 0.2 in figure 3. However, having an equation start with *"Figure"* is not always optimal. The German "Abbildung" is even worse.

$$x^2 + y^2 = z^2 \tag{0.2}$$

Figure 3: Pythagorean Theorem

CGV specific notation and symbols

In CG we work with 2D, 3D and 4D vectors $v \in \mathbb{R}^d$. Vectors can represent different entities. At the CGV lab, we use the notation shown in figure 4 for them. All the notations can also be looked up in the slides of the cg-courses.

0.2.5 Tables

In Latex, tables are generated using the tabular environment. As this is often far more complicated then in editors following the *What You See Is What You Get (WYSIWYG)* principle, a tool for building tables in a WYSIWYG manner and translating them to Latex-Code can be useful. Examples for such tools are latex-tables.com[3] and tablesgenerator.com[4]. When creating tables, there should generally be no vertical lines and only three horizontal lines[5][6]. A table in latex might look like table 2. The code for creating this table can be found in the code box 5. Please note: In contrast to figures, tables must have the caption above the content and also and also should be placed at the top of a page, which is achievable by using the placement parameter `[t]`. For very long tables, the `longtable`-package[7] might help with its support for tables spanning multiple pages.

0.2.6 Code

With the `lstlisting` environment you can show code. The most important difference to normal text is, that spaces and tabs are kept in place within that environment and

[3] https://www.latex-tables.com/
[4] https://www.tablesgenerator.com/
[5] A neat little guide on how to make tables look nice can be found here: https://people.inf.ethz.ch/markusp/teaching/guides/guide-tables.pdf
[6] Another helpful source about tables might be this blog post by Nick Higham: https://nhigham.com/2019/11/19/better-latex-tables-with-booktabs/
[7] For reading even more about tables and the possible packages, this wikibooks entry could be interesting: https://en.wikibooks.org/wiki/LaTeX/Tables

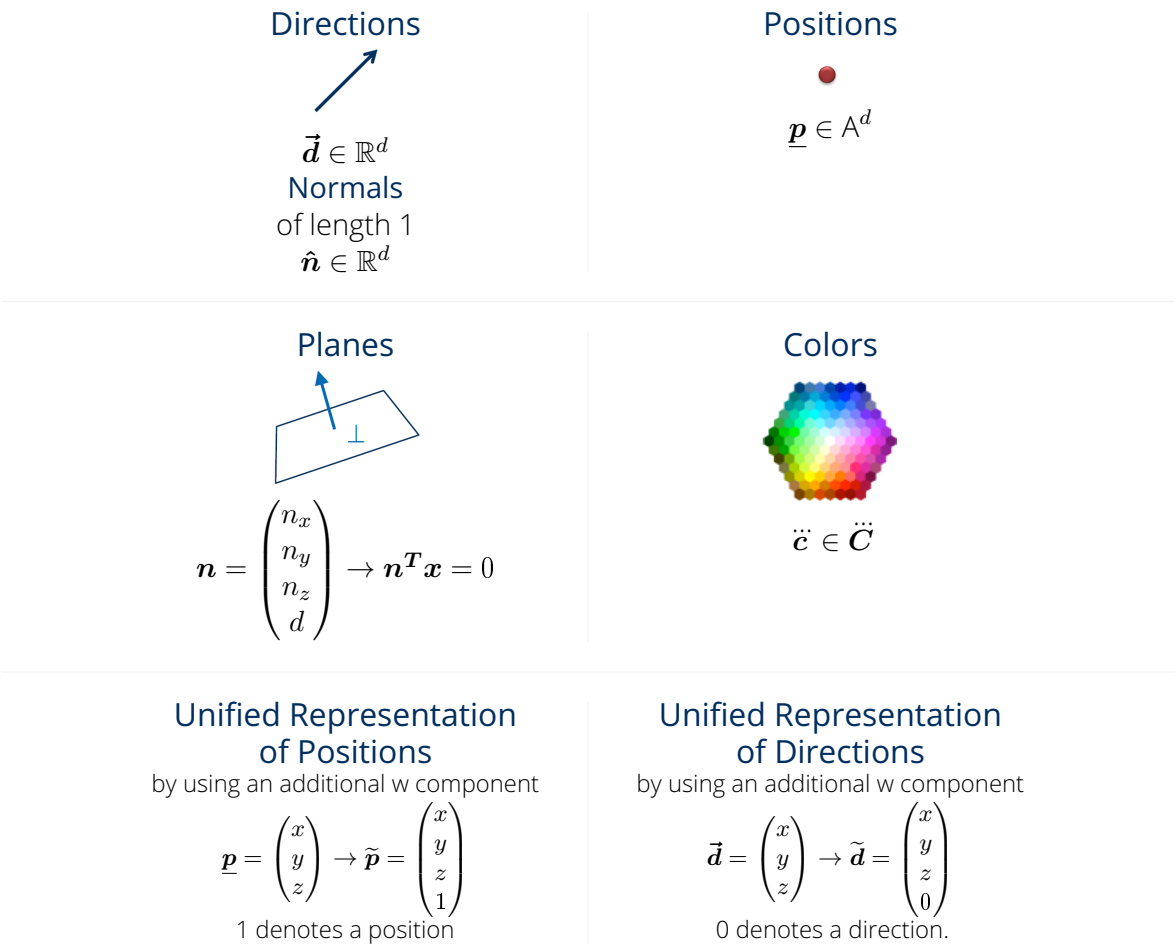

Figure 4: Some of the different notations for multiple types of vectors. All the notation types can be looked up in the computer graphics lecture slides.

Table 2: Average absolute error in slices and percentage, by size of implementation. This table is from a paper from Milder et al. [**Milder2006**].

slices	abs. Error (%)		abs. Error (slices)	
	avg.	max.	avg.	max.
<5000	7.4	75.0	118	835
5000-10000	2.4	14.4	162	756
10000-15000	2.0	11.5	232	1235
>15000	2.3	14.5	438	2287

Latex commands will not be executed. You can however escape latex commands with the [escapeinside=][8] option. An example for how to show code can be seen in 6, which results in 7.

[8]Here is an example on how to do that: https://tex.stackexchange.com/questions/63729/

```
\begin{table}[t]
        \centering
        \caption{Average absolute error in slices and percentage, by size of implementation. This
             table is from a paper from Milder et al. \cite{Milder2006}.}
        \renewcommand{\arraystretch}{1.3}
        \begin{tabular}{@{}rrrcrrc@{}}\toprule
                \multicolumn{1}{l}{slices} & \multicolumn{2}{c}{abs. Error (\%)} & \phantom{abc}&
                \multicolumn{2}{c}{abs. Error (slices)}\\
                \cmidrule{2-3} \cmidrule{5-6}
                                & avg.  & max.  && avg. & max   \\ \midrule
                <5000           & 7.4   & 75.0  && 118  & 835   \\
                5000-10000      & 2.4   & 14.4  && 162  & 756   \\
                10000-15000 & 2.0       & 11.5  && 232  & 1235  \\
                >15000          & 2.3   & 14.5  && 438  & 2287  \\
                \bottomrule
        \end{tabular}
        \label{tab:example}
\end{table}
```

Figure 5: Code for the example table 2

```
\begin{figure}[htbp]
        \begin{lstlisting}
//comment
for(int i = 0; i < 100;i++)
{
        test(i);
}
        \end{lstlisting}
        \caption{Example for a code block.}
        \label{code:example}
\end{figure}
```

Figure 6: Code for showing the code block below. As tabs are preserved in listings, there should be no tabs in the code, that you do not want to see in the output.

```
//comment
for(int i = 0; i < 100;i++)
{
        test(i);
}
```

Figure 7: Example for a code block.

1 Introduction

The human brain consists of 86 billion neurons. Even if one wanted to pick out, visualize and examine just a tiny fraction of these, it would be very difficult to make any meaningful conclusions, as the sheer volume of data prevents close inspection. Nevertheless, correct and precise analysis of datasets is a cornerstone of any research, but this is often challenging and error-prone, especially when the complexity and size of the dataset increases. A common problem with such large data sets is that the data you are trying to examine is obscured and blocked by other data, this is especially the case with three dimensional data sets and is called occlusion. Therefore, it is important to develop methods and programs that filter or transform data sets and allow a closer look at individual parts of the data set as well as their context. There are many different techniques to avoid and reduce occlusion. These methods can roughly be divided into two types: hiding unimportant data and transforming the data set so that occlusion is avoided. For example, it is possible to use clipping planes to hide foreground data. A common problem with using them is that the context of the data is difficult to recognize, because only a part of the whole is shown. To reduce this, the position of individual data can be changed so that no more occlusion occurs, but all data is still displayed. One way of transforming the data set is through the use of exploded views. Here, individual parts of a model or data set are pulled apart in such a way that each part of interest can be viewed in detail and the original composition of the data set remains recognizable.

The goal of this work is to examine and compare different methods for generating such exploded views for cell complexes. Furthermore, it will be tested which of these methods are suitable for inspection in virtual reality and what new possibilities and difficulties this innovative environment brings. Since the immersive visualization of such models in virtual reality and its intuitive interaction creates completely new possibilities for exploded views, it is important to find out which techniques are effective and which established methods are not suitable. To do this, a prototypical implementation of some selected techniques for exploded views is performed and compared. For this purpose, a data set of a cell complex is available which is visualized and transformed. This dataset was simulated and it describes the change of the cell complex over a defined period of time. Therefore it is necessary that the visualization and the explosion view can also show the temporal change of the individual cells of the cell complex. Furthermore, different interaction types are to be tested.

In order to achieve this, the work is divided into the following structure. First, general terminologies and problems of exploded views are explained, then a thorough literature analysis takes place on related works and their solution approaches on the subject of occlusion avoidance of dynamic and static data sets. It continues with a more precise classification of the topic and the solution approaches that are pursued in this work. Then the results are shown and explained in a subsequent discussion. At the end there is a summary of the work as well as further approaches that could be explored in a future work.

2 Background

3 Related Work

Describing the research field with relevant works on the same or similar issues.

4 Methods and Implementation

5 Results

6 Conclusion and Further Work

List of Figures

List of Tables

A Appendix I

Hello, here is some text without a meaning. 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. 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. Hello, here is some text without a meaning. 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. 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. Hello, here is some text without a meaning. 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. 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.

B Appendix II

Hello, here is some text without a meaning. 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. 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. Hello, here is some text without a meaning. 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. 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. Hello, here is some text without a meaning. 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. 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.