UNIVERSITÄT
BERN

Stable Neo-Hookean Flesh Simulation

Bachelor Thesis

submitted in fulfilment of the requirements for the degree of
Bachelor of Science (B.Sc.)

at the

University of Bern
Institute of Computer Science

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Eingereicht von:	Corina Danja Masanti
Matrikelnummer:	15-128-655
Datum der Abgabe:	01.09.2019

Vorwort

Dies ist ein Vorwort

Abstract

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

Inhaltsverzeichnis

Kapitel 1

Introduction

1.1 Motivation

The goal of this work is for a regular computer science student to give the necessary physical and mathematical background to understand the field of animation.

1.2 Structure

I will start with the background and then go on to the actual paper.

Kapitel 2

Background

This chapter will provide the necessary background in continuum mechanics and mathematics in order to understand the next chapters.

In this chapter we will examine the topic of the paper *Stable Neo-Hookean Flesh Simulation*. The goal of the paper was to model deformations for virtual characters that have human-like features.

2.1 Notation and Convention

At first we will declare the notation used in this thesis to avoid misunderstandings. We will use the common notation used in continuum mechanics and additionally we will include the declarations in the paper *Stable Neo-Hookean Flesh Simulation*.
Scalars are represented by regular, normal-weight variables whereas tensors and matrices are represented by upper-case bold variables such as $\mathbf{F}$. Vectors will be denoted by bold lower-case variables.
Furthermore we will use the tensor notation used in the paper *Stable Neo-Hookean Flesh Simulation*. They decided to to define vectorization vec(.) as column-wise flattening of a matrix into a vector ([**Smith:2018:SNF:3191713.3180491**], 12:5) similar to Golub and Van Loan (2012):

$$\mathbf{A} = \begin{bmatrix} a & c \\ b & d \end{bmatrix} \qquad vec(\mathbf{A}) = \check{\boldsymbol{a}} = \begin{bmatrix} a \\ b \\ c \\ d \end{bmatrix}.$$

In order to indicate that we are dealing with a vectorized matrix we will use the symbol $\check{\cdot}$ as shown above.

2.2 Mathematical Background

Since mathematics plays an important role in our field of interest we will build a solid background in this chapter. A basic understanding of linear algebra is assumed.

2.2.1 Matrices

At first we will discuss the geometrical meaning of some common matrix properties.

2.2.2 Singular Value Decomposition

The singular value decomposition (SVD) will play an important role in the following. It is important for our application since it represents the best possible approximation of a given matrix by a matrix of low rank. This approximation can be looked at as a compression of the data given ([LM15], S. 295).

2.3 Continuum Mechanics

In this section we will give a broad introduction the field of Continuum Mechanics. In Continuum Mechanics we are less interested in small particles like atoms or molecules of an object but concentrate on pieces of matter which are in comparison very large. We are therefore concerned with the mechanical behavior of solids and fluids on the macroscopic scale ([Spe80], S. 1).

2.4 Deformation

Graphically we can imagine a deformation with the help of a deformation map. In Fig. 4.1 we have on the left side an ellipse that signifies an object in its rest state. On the right side in the same image we can see the ellipse in a deformed state. We can map each point from its rest state to the deformed one with the help of the function ϕ.

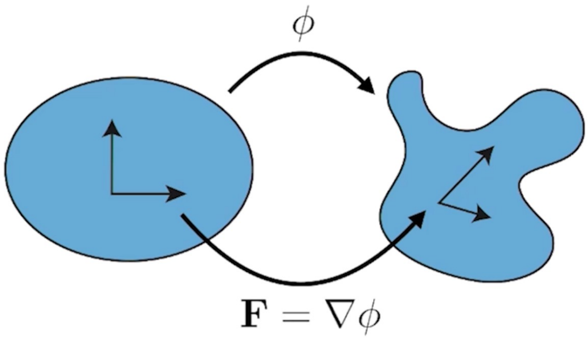

Abbildung 2.1: Deformation Map [Pix]

When applying a force over an object naturally the object itself undergoes a deformation. In the following we will be consistent with most previous literature in continuum mechanics and use the term strain as a measure of deformation and stress as the force per unit area.

$$Strain = measure\ of\ deformation$$
$$Stress = force\ per\ unit\ area$$

2.5 Deformation Gradient

The deformation gradient F is also shown in Fig. 4.1. It offers us a measurement of the deformation. With its help we can amongst other things calculate the volume and length change an object undergoes during a deformation. For our needs we define the deformation gradient as followed:

$$\mathbf{F} = \left[\, f_0 \,\middle|\, f_1 \,\middle|\, f_2 \,\right] = \begin{bmatrix} f_0 & f_3 & f_6 \\ f_1 & f_4 & f_7 \\ f_2 & f_5 & f_8 \end{bmatrix}$$

Measure for the deformation, length and volume change etc. Nonlinear deformations http://www.continuummechanics.org/deformationgradient.html also add some examples

2.6 Material Constants

Naturally the properties of the material the object consists of play an important rule in the deformation process. The two constants μ and λ that are crucial for us are called *Lamé Parameters*. The formula in which they appear is called *Poisso's Ratio* and is of the following form:

$$\sigma = \frac{\lambda}{2(\lambda + \mu)} \in [-1, 0.5]$$

The poisson's ratio is of importance for us since it characterizes the materials resistance to volume change. Usually the poisson's ratio of a material is positive.
For the simulation of human-like flesh we have to choose a poisson's ratio that is almost 0.5 to get realistic results.
further reading: http://silver.neep.wisc.edu/ lakes/PoissonIntro.html

2.7 Deformation Energy

In order to get a convincing simulation of high quality we must choose an appropriate energy. In the case of modelling deformations on human-like characters we have to choose an elastic energy. The key property that makes an energy elastic is that if all the forces that are applied over an object add up to zero the object must come back to its rest shape. The energy then has to be minimized to get the results we want.

Definition 1. *This is a definition.*

Kapitel 3

Background

This chapter will provide the necessary background in continuum mechanics and mathematics in order to understand the next chapters.

3.1 Notation

At first we will declare the notation used in this thesis to avoid misunderstandings. We will use the common notation used in continuum mechanics.

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Since mathematics plays an important role in our field of interest we will build a solid background in this chapter. A basic understanding of linear algebra is assumed.

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3.4 Test

Nachfolgend der Codeauszug 3.1.

```java
/**
* The HelloWorldApp class implements an application that
* simply prints "Hello World!" to standard output.
*/
class HelloWorldApp {
  public static void main(String[] args) {
    System.out.println("Hello World!"); // Display the string.
  }
}
```

Codeauszug 3.1: Hello World

3.5 Bild

Die rechts zu sehende Grafik demonstriert die Möglichkeiten des Paketes „wrapfig“. Grafiken innerhalb einer „wrapfigure“ können entweder links oder rechts von Text umlaufen werden.

Abbildung 3.1: Beispielbild [PEX]

Die nachfolgende Abbildung 3.2 demonstriert die Darstellung eines „*.jpg“ Bildes innerhalb des Textes (beim Einfügen kann auf die Endung verzichtet werden, solange der Name einzigartig ist). Zusätzlich enthält dieses einen Untertitel der über das bereits verwendete Label verlinkt werden kann. Der Untertitel erscheint im Abbildungsverzeichnis (Abbvz.).

3.6 Text Formatierungen und sonstiges

Dieser Text enthält eine Fußnote[1].

3.6.1 Listen

Listen könne sowohl mit Bullet points als auch mit Zahlen erstellt werden

- Eine Liste mit Bullet points
- Ein weiteres Element

1. Eine Liste mit Zahlen

[1] Fußnoten sind Anmerkungen, die im Druck-Layout aus dem Fließtext ausgelagert werden, um den Text flüssig lesbar zu gestalten.

2. Ein weiteres Element

3.6.2 Text Hervorhebungen

> The problem with internet quotes is that you can't always depend on their accuracy
>
> — Abraham Lincoln, 1864

Ïnspirierende Zitate können mit epigraph eingefügt werden

> The problem with internet quotes is that you can't always depend on their accuracy
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> Abraham Lincoln, 1864

Seitenumbrüche können nur direkt nach Text geschrieben werden, sonst lässt sich das Latex nicht mehr compilieren.

Abbildung 3.2: Beispielbild [PEX]

3.7 Tabelle

Nachfolgend Tabelle 3.1.

Inhaber: Alice
Peer (Ersteller): Bob
Öffentlicher Schlüssel des Inhabers: F2 D2 0E ED FA 4E 9E 0A F2 DD 23 8A 32 44 F3 E9
Gültigkeit: 2015-07-01 – 2016-06-30

Tabelle 3.1: Digitales Zertifikat

3.8 Long-Table

Die „Long-Table“kann über definierte Header und Footer über Seitenumbrüche hinweg angezeigt werden.

Version	Codename	API	Verteilung
2.2	Froyo	8	0.1%
2.3.3 - 2.3.7	Gingerbread	10	2.7%
4.0.3 - 4.0.4	Ice Cream Sandwich	15	2.5%
4.1.x	Jelly Bean	16	8.8%
4.2.x		17	11.7%
4.3		18	3.4%
4.4	KitKat	19	35.5%

Fortsetzung auf nachfolgender Seite

Fortsetzung - Verteilung der Androidversionen (Stand 01.02.2016)

Version	**Codename**	**API**	**Verteilung**
5.0	Lollipop	21	17.0%
5.1		22	17.1%
6.0	Marshmallow	23	1.2%

Tabelle 3.2: Verteilung der Androidversionen (Stand: 01.02.2016)

3.9 Literaturverweis

Weil für die alte und die neue Rechtschreibung verschiedene Trennregeln gelten, sind Deutsch mit alter Rechtschreibung und Deutsch mit neuer Rechtschreibung zwei verschiedene Sprachen ([Kna09], S. 192).

3.10 Onlineverweise

Siehe Google.de [Goo].

3.11 Glossar

Der Glossar enthält die Beschreibung verwendeter Begriffe für das bessere Verständnis gegenüber dem Leser. Beispiele sind: Berlin, Outsourcing, Application Service Providing, Policy und PCI Express.

3.12 Abkürzungsverzeichnis

Das Abkürzungsverzeichnis listet alle verwendeten Abkürzungen auf. Einige Beispiele sind Serial Attached SCSI (SAS), Compact Disk (CD), Local Area Network (LAN) und

Internationale Organisation für Normung (ISO). Die erneute Verwendung zeigt nur noch die Abkürzung: SAS, CD, LAN und ISO.

Kapitel 4

Paper

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4.1 Deformation

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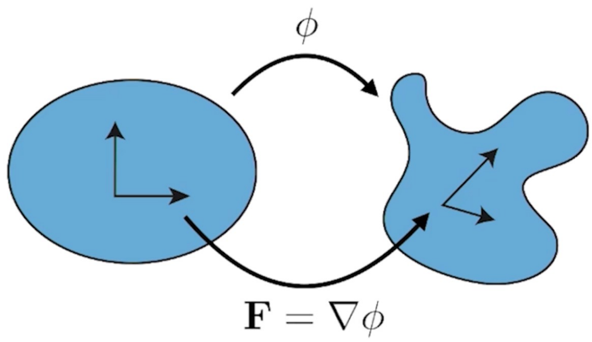

Abbildung 4.1: Deformation Map [Pix]

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Definition 2. *This is a definition.*

Abbildungsverzeichnis

Tabellenverzeichnis

Quelltextverzeichnis

Stichwortverzeichnis

Literaturverzeichnis

[Kna09] Joerg Knappen. *Schnell ans Ziel mit LATEX 2e* -. ueberarbeitete und erweiterte Auflage. Muenchen: Oldenbourg Verlag, 2009. ISBN: 978-3-486-59015-9.

[LM15] Joerg Liesen und Volker Mehrmann. *Linear algebra*. 1st ed. 2015. Springer International Publishing, Switzerland 2015: Springer, Cham, 2015. ISBN: 978-3-319-24344-3.

[Spe80] A. J. M. Spencer. *Continuum Mechanics*. 2004. Aufl. 31 East 2nd Street, Mineola, N.Y. 11501: Dover Publications, Inc., 1980. ISBN: 0-486-43594-6 (pbk.)

Onlinequellen

[Goo] Google. *Google*. URL: `http://www.google.de` (besucht am 06. 10. 2015).

Bildquellen

[PEX] PEXELS. *Black and white branches tree.* URL: https://www.pexels.com/photo/black-and-white-branches-tree-high-279/.

[Pix] Pixar. *Deformation Map.* URL: https://dl.acm.org/ft_gateway.cfm?id=3180491&ftid=2009597.

Anhang A

A.1 Diagramm

A.2 Tabelle

A.3 Screenshot

A.4 Graph

Eigenständigkeitserklärung

Hiermit versichere ich, dass ich die vorliegende Masterarbeit selbstständig und nur unter Verwendung der angegebenen Quellen und Hilfsmittel verfasst habe. Die Arbeit wurde bisher in gleicher oder ähnlicher Form keiner anderen Prüfungsbehörde vorgelegt.

Stadt, den xx.xx.xxxx

Max Mustermann