Motion Sickness Reduction for 6-DoF-Navigation in a Virtual Solar System

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Master Thesis

Hochschule Hannover
Faculty IV – Business and Computer Science
Course of Studies M. Sc. Applied Computer Sciences

February 15, 2021

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Declaration of Authorship

I hereby declare that this thesis, and the work presented in it are my own and has been generated by me as the result of my own original research. I confirm that:

1. Where I have consulted the published work of others, this is always clearly attributed.
2. Where I have quoted from the work of others, the source is always given. Except for such quotations, this thesis is entirely my own work.
3. I have acknowledged all main sources of help.
4. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

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Contents

1 Background and Related Work

While Virtual Reality technology has gained more and more traction over the recent years, 30% to 80% of users encounter some form of sickness symptoms during exposure to virtual reality environments [1]. Additionally, these sickness symptoms not only occur during exposure, but can have lasting effects and affect users after the exposure as well [2]. The high number of affected users has led to cybersickness being one of, if not the biggest roadblock to a more widespread adoption of Virtual Reality Devices.

According to LaViola [2] the symptoms of exposure to Virtual Reality environments include:

- Eye strain
- Headache
- Pallor
- Sweating
- Dryness of mouth
- Fullness of stomach
- Disorientation
- Vertigo
- Nausea
- Vomiting.

Vertigo, in the case of VR-sickness specially benign paroxysmal positional vertigo (BPPV), is a condition where the individual experiences a false sense of motion, or spinning and objects or surroundings appear to swirl or move [3].

Throughout the study of these symptoms, several terms have been used to compound these sickness symptoms that appear to be similar to motion sickness symptoms. Initially, the term Simulator Sickness was used to describe motion sickness encountered during exposure to flight simulators and originated from the assessment of military flight simulators [4, 5]. While Simulator Sickness is still used in recent publications, the terms Cybersickness or VR Sickness are generally used to differentiate from simulator sickness and closer examine the side effects resulting from the use of virtual environments [4, 6]. The term VR Sickness specifically is used in discussions and studies about sickness symptoms involving head-mounted displays (HMD) [7, 8]. Here, the terms Cybersickness and VR Sickness will be used, as Stanney, Kennedy, and Drexler [9] argue that sickness from virtual environments shares many of the symptoms often also experienced during simulator sickness or motion sickness, but the sickness profiles being different. The main arguments for this distinction are that during cybersickness, disorientation symptoms rank highest and oculomotor symptoms lowest, while simulator sickness and traditional motion sickness usually have the inverted profile, where disorientation symptoms rank lowest [9]. Cybersickness can also occur without stimulation to the vestibular system, purely through visual cues, unlike motion and simulator sickness, where

2 Chapter 1

This is a template you can use for your thesis. In the following some examples will be given how to use the template features.

2.1 Some Section

This is a section with some text.

2.2 Lists

This is a list:

- First item
- Second item
- Third item

2.3 Images

2.3.1 Simple Image

This is an image:

Figure 2.1: This is the image caption. The image is from Limberger et al. [10].

2.3.2 Image Comparison

Figure 2.2: Here you can see two images next to another for comparison.

2.4 Citations and References

This is a citation: Limberger et al. [10].

This is a reference to the Appendix A.

This is a reference to an image 2.1.

Here are some more citations for example purposes at the end of the paper:

- Inproceedings [11]
- Article [12]
- Website [13]
- Tech Report [14]
- Master Thesis [15]
- Book [16]

3 Chapter 2

3.1 Formulas

This is a text that describes a formula. This formula is for calculating the brightness of light for a single point that is illuminated by the sun and partially occluded by a moon. This is done by taking the solid angle of the Sun Ω_{sun} subtracting the solid angle of the occluding moon Ω_{occ} and normalize the result. To the right we have a table that describes all the symbols that appear on this page, so people can much more easily see what symbol has which meaning without having to reread the text everytime they want to use the formula.

Symbols	
I	relative brightness
Ω_{sun}	solid angle of the sun
Ω_{occ}	solid angle of intersection

$$I = \frac{\Omega_{sun} - \Omega_{occ}}{\Omega_{sun}}. \tag{3.1}$$

3.2 Units in Equations

$$\frac{6371\,\mathrm{km} * 149\,600\,000\,\mathrm{km}}{695\,510\,\mathrm{km} - 6371\,\mathrm{km}} = 1\,383\,000\,\mathrm{km}. \tag{3.2}$$

3.3 Code Blocks

This templated uses minted for formatting code. It is required to install the python package Pygments. You can do this with the following command: pip install Pygments

3.3.1 Simple Code Block

Here we can see a code block. The second argument specifies the language for text highlighting.

```
// Get the intensity of the eclipse caused by the occluding body for our fragment.
float eclipseLight = calcEclipse(occludingBody, fragPos);

// Get the color of the fragment from the bodies texture.
outputColor = texture(/*...*/);

// Reduce the brightness of the fragment according to the intensity of the eclipse.
outputColor = outputColor * eclipseLight;
```

3.3.2 Imported Code Block from File

The following line imports code from a text file. The first argument is the language for highlighting purposes.

```
// Get the intensity of the eclipse caused by the occluding body for our fragment.
float eclipseLight = calcEclipse(occludingBody, fragPos);

// Get the color of the fragment from the bodies texture.
outputColor = texture(/*...*/);

// Reduce the brightness of the fragment according to the intensity of the eclipse.
outputColor = outputColor * eclipseLight;
```

3.3.3 Inline Code

This is inlined code: `float calcEclipse(vec4 occludingBody, vec3 fragmentPosition)`, where the first argument is the language.

3.4 Tables

This is a table:

Body	**Semi-major Axis**	**Observer Placement**	**Max. Abs. Error**
Mercury	0.39 AU	surface	0.0008
		500,000km	0.0000
Venus	0.72 AU	surface	0.0004
		500,000km	0.0000
Earth	1.00 AU	surface	0.0003
		Moon	0.0000
Mars	1.52 AU	surface	0.0002
		Phobos	0.0000
		Deimos	0.0000
Jupiter	5.20 AU	surface	0.0000
		Io	0.0000
		Callisto	0.0000

Table 3.1: This is the table caption.

A Appendix

This is the appendix. You can put all the stuff you like here.

A.1 Appendix Sections

The enumeration for the appendix is different.

Bibliography

[1] Rebenitsch, L. and C. Owen: *Review on cybersickness in applications and visual displays*. In *Virtual Reality*, vol. 20, pp. 101–125, 2016. https://link.springer.com/article/10.1007%2Fs10055-016-0285-9.

[2] LaViola, J. J.: *A discussion of cybersickness in virtual environments*. SIGCHI Bull., 32(1):47–56, 1 2000. https://doi.org/10.1145/333329.333344.

[3] Post, R. E. and L. M. Dickerson: *Dizziness: a diagnostic approach*. American family physician, 82(4):361–368, 8 2010. https://www.aafp.org/afp/2010/0815/p361.html, PMID: 20704166.

[4] Saredakis, D., A. Szpak, B. Birckhead, H. A. D. Keage, A. Rizzo, and T. Loetscher: *Factors associated with virtual reality sickness in head-mounted displays: A systematic review and meta-analysis*. Frontiers in Human Neuroscience, 14:96, 2020. https://www.frontiersin.org/articles/10.3389/fnhum.2020.00096/full.

[5] Kennedy, R. S., N. E. Lane, K. S. Berbaum, and M. G. Lilienthal: *Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness*. The International Journal of Aviation Psychology, pp. 203–220, 1993. https://doi.org/10.1207/s15327108ijap0303_3.

[6] McCauley, M. E. and T. J. Sharkey: *Cybersickness: Perception of self-motion in virtual environments*. In *Presence: Virtual and Augmented Reality*, vol. 1, pp. 311–318, 1992. https://doi.org/10.1162/pres.1992.1.3.311.

[7] Kim, H. K., J. Park, Y. Choi, and M. Choe: *Virtual reality sickness questionnaire (vrsq): Motion sickness measurement index in a virtual reality environment*. Applied Ergonomics, 69:66–73, 2018. https://www.sciencedirect.com/science/article/pii/S000368701730282X.

[8] Cobb, S. V. G., S. Nichols, A. Ramsey, and J. R. Wilson: *Virtual reality-induced symptoms and effects (vrise)*. In *Presence: Virtual and Augmented Reality*, vol. 8, pp. 169–186, 1999. https://doi.org/10.1162/105474699566152.

[9] Stanney, K. M., R. S. Kennedy, and J. M. Drexler: *Cybersickness is not simulator sickness*. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, vol. 41, pp. 1138–1142, 10 1997. https://doi.org/10.1177/107118139704100292.

[10] Limberger, D., J. Engel, and J. Döllner: *Single-pass rendering of day and night sky phenomena*. pp. 55–62, 11 2012. https://pdfs.semanticscholar.org/fce4/4229921fcb850540a636bd28b33e30b18c3f.pdf.

[11] Yapo, T. C. and B. Cutler: *Rendering lunar eclipses*. In *Proceedings of Graphics Interface 2009*, GI '09, pp. 63–69, Toronto, Ont., Canada, Canada, 2009. Canadian Information Processing Society, ISBN 978-1-56881-470-4. https://www.cs.rpi.edu/~cutler/publications/yapo_gi09.pdf.

[12] Williams, L.: *Casting curved shadows on curved surfaces*. SIGGRAPH Comput. Graph., 12(3):270–274, Aug. 1978, ISSN 0097-8930. http://doi.acm.org/10.1145/965139.807402.

[13] Celestia Development Team: *Celestia - real-time 3d visualization of space*. https://celestia.space/, Accessed: 2019-08-20.

[14] NASA: *U.s. standard atmosphere*. Techn. rep., NASA, NOAA, USAF, Washington, D.C., October 1976. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19770009539.pdf.

[15] Fischer, T.: *Comparison of gpgpu frameworks related to game development*, September 2018. https://drive.google.com/file/d/1zX-Etv1JVO_i-J84vgr-hjXYKyGIQQgM/view.

[16] Bohren, C. F. and D. R. Huffman: *Absorption and Scattering of Light by Small Particles*. Wiley-VCH, 1998, ISBN 9780471293408.