NTNU – Trondheim
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Towards a 3D model of the rat brain in AR as an educational tool

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PROJECT THESIS
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Preface

Here, you give a brief introduction to your work. What it is (e.g., a Master's thesis in RAMS at NTNU as part of the study program xxx and...), when it was carried out (e.g., during the autumn semester of 2021). If the project has been carried out for a company, you should mention this and also describe the cooperation with the company. You may also describe how the idea to the project was brought up.
You should also specify the assumed background of the readers of this report (who are you writing for).

Trondheim, 2012-12-16

(Your signature)

Ola Nordmann

Acknowledgment

I would like to thank the following persons for their great help during . . .
If the project has been carried out in cooperation with an external partner (e.g., a company), you should acknowledge the contribution and give thanks to the involved persons. You should also acknowledge the contributions made by your supervisor(s).

O.N.

(Your initials)

Remark:

Given the opportunity here, the RAMS group would recognize Professor Emeritus Marvin Rausand for the work to prepare this template. Some minor modifications have been proposed by Professor Mary Ann Lundteigen, but these are minor compared to the contribution by Rausand.

Executive Summary

Here you give a summary of your your work and your results. This is like a management summary and should be written in a clear and easy language, without many difficult terms and without abbreviations. Everything you present here must be treated in more detail in the main report. You should not give any references to the report in the summary – just explain what you have done and what you have found out. The Summary and Conclusions should be no more than two pages.
You may assume that you have got three minutes to present to the Rector of NTNU what you have done and what you have found out as part of your thesis. (He is an intelligent person, but does not know much about your field of expertise.)

Contents

Chapter 1

Introduction

I feel I need the two following sections before the Motivation sections, as they are quick introductions to the basics. But maybe there is a better way?

Augmented Reality

Augmented Reality (AR) describes the use of computer technology to generate an audio-visual experience combining real-world impressions with computer generated graphics, and, *essentially*, the ability to interact seamlessly within both domains. Ever since its infancy medical usage of AR technology has been envisioned as a great potential. The idea of x-ray vision is seen both in science fiction and in genuine research dating all the way back to the 1930s when H. Steinhaus explored ways to visualize metal pieces inside the body (Sielhorst et al., 2008). There is now substantial interest in the use of AR within a wide array of medical fields as well as in industry and education. As an emerging technology there is still much research needed, and great leaps in hardware, software and sensor capabilities are bound to happen in the near future. Already AR shows promising results in both surgical settings and in education (Singh and Kharb, 2013).

Neuroanatomy

The study of neuroanatomy is concerned with the structural organization of the nervous system. This primarily means the brain and its structures, and is what this project will focus exclusively on. Within the study of neuroanatomy, the use of macroscopical brain dissections have long been the conventual practice for teaching the organization of the structures in the brain. Requiring cadavers and the single use of their brain, this method is highly resource intensive and has limited scalability. In addition, there are deeply concerning ethical challenges with the use of animals in research, which will be discussed further in section 2.3.

1.1 Motivation

In light of the problems with physical brain dissections it is natural that the use of digital tools, three-dimensional modeling and visualization has been seeing growing use for educational purposes.

According to (Dalgarno and Lee, 2010) computer-aided learning generally increases understanding for anatomy. As anatomy in general, and neuroanatomy specifically are highly complex domains both visually and spatially, the ability to use the human senses in a real-world setting could result in greater intuition and understanding. With that in mind the use of augmented reality could be a natural way to virtualize the experience of a brain dissection, and further the unique capabilities of AR could enable innovative ways of learning. (Moro et al., 2017) shows the possibility of greater immersion and engagement while using augmented reality in teaching anatomy to medical students. This has also recently been shown with promising result by (Wish-Baratz et al., 2020), where COVID-lockdown required from-home teaching, and the use of HoloAnatomy, an anatomy application for the HoloLens, performed significantly better than even conventional in-class lectures.

The main problem with most academic implementations, like (Wish-Baratz et al., 2020), of AR in medical education is the use of head-mounted display (HMD) devices like the HoloLens 2 and Magic Leap, which in the near to mid-term future will have limited practical use in education, as a result of the high price-tag, combined with the still inadequate general use-case for these types of devices. This project will try to mend these challenges by having the lecturer using an HMD and having student view and interact with the lecture in an AR-based application running on their smartphone. This is possible because of the great leap in AR-performance seen in recent models of Android and especially iPhones, in combination with development platforms like Unity 3D, Mixed Reality Toolkit and Photon (see section 3.1) which enables multiplatform development and real-time collaboration between devices.

Introduce Nevrolens and WHS brain

The aim of the project will be to create a seamless educational experience in Augmented Reality which can be valuable both on an HMD device and a modern smartphone. The focus will be on investigating its feasibility as an educational tool both in a lecture-type setting and for students to explore the brain anatomy independently.

1.2 Problem Formulation

What Remains to be Done?

1.3 Objectives / Research Questions

What follow are the research questions which motivates this project:
Main RQ: How can AR support teaching of rat brain anatomy and dissection for medical students?

- **Sub-RQ1:** How should interaction in be implemented in AR to accommodate medical professionals?
- **Sub-RQ2:** How will a collaborative experience shared between an HMD and a smartphone compare to accommodate medical professionals?
  Sub-RQ3: Something about macro + microscopic visualization, some suggestions:
- Can microscopical data seamlessly be integrated into a macroscopical model?
- Can understanding be increased by integrating microscopical data into a macroscopical model?
- Will having integrated microscopical data in a macroscopical model lead to greater understanding?

1.4 Approach

Research method

The research questions were derived through discussing the needs of the intended users with neuroscientists at the Kavli Institute. It was then narrowed down by a literature review, finding a lack of satisfactory substitutions for real brain dissections and especially finding no attempt at a practical multiplatform application for a more scalable use for students. The projects research question falls under the strategy of Design and Creation as the main goal is to develop a useful application for medical education. The focus on a smartphone solution was further motivated by the COVID-pandemic making from-home learning quite essential and making the passing around of HMD devices an unwanted scenario. As part of an agile software development model the gathering of qualitative data from observations and interviews within the scope of user testing will be essential.

Development method

1.5 Contributions

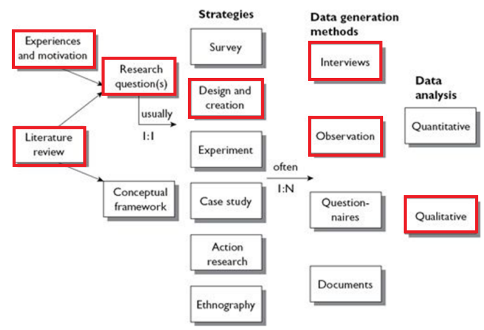

Figure 1.1: Model of the research process as illustrated in Oates (2006)

The research product resulting from this project will be a new computer-based software application using augmented reality and running on multiple platforms like HoloLens 1 and 2, Android and more. The aim will be to develop an application that can bridge the gap between expensive head mounted displays and everyday smartphones which you will find in the pocket of any student, and to use this as a collaborative tool for learning neuroanatomy. Throughout the development period we will consult with medical professionals and gather feedback from students on the usability of the application.

Something about macro + micro

1.6 Limitations

1.7 Outline

Chapter 2

Background

2.1 Augmented Reality

(Jentoft, 2020) AR can be defined as a system that fulfills three basic features: a combination of real and virtual worlds, real-time interaction, and accurate 3D registration of virtual and real objects.

2.2 Graphics and Rendering

Rasterization, Polygons and 3D models

I feel that there is some misunderstanding about what a 3D model is. Maybe go in-depth about what I mean by 3D model. I have probably already used the term for different things.

2.3 Neuro stuff

Ethics of dissection

The Waxholm Space Atlas of the Sprague Dawley Rat Brain

https://www.nitrc.org/projects/whs-sd-atlas

- What is a atlas
- WHS and ratbrain is open, used and developed by NTNU St Olavs and UiO

- Waxholm Space Atlas of the Sprague Dawley Rat Brain
- Discuss difference between graphical 3D model and 3D atlas

This project makes use of high-resolution 3D-models of a rat brain. This brain model has been captured and manually delineated[1] by a collaboration between research groups at the University of Oslo and NTNU, and is in fact a highly accurate volumetric representations of the rat brain. This model is an open access community resource, intended as a free tool for education and research[2]. Within the convectional rasterization rendering pipe-line of Nevrolens, a polygonal asset derived from this volumetric model is naturally used.
The model is simply referred to as *The Waxholm Space Atlas of the Sprague Dawley Rat Brain*. What follows is a brief explanation of each confusing part of the this name.

Waxholm Space

Waxholm Space (WHS) is a vector space defined as a standard reference space for the mouse brain and the rat brain (Papp et al., 2013). Its use as a coordinate system simplifies interoperability across atlases. It was developed by International Neuroinformatics Coordinating Facility (INCF) for the mouse brain, and has further been implemented in the rat brain by Papp et al. (2014). The following is the formal definition of WHS:

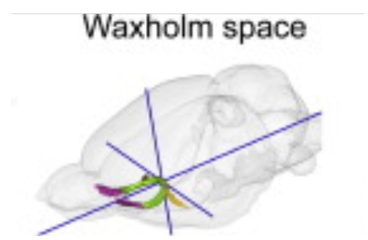

Figure 2.1: WHS (Papp et al., 2014)

> *The coordinate system for WHS is defined as a continuous Cartesian system with the origin in the brain determined by*
>
> - *the anterior commissure (AC) at the intersection between the mid sagittal plane,*
> - *a coronal plane passing midway (rostro-caudal) through the anterior and posterior branches of AC, and*
> - *a horizontal plane passing midway through the most dorsal and ventral aspect of the AC.*

[1]Delineation refers to the process of clearly defining different structures in the brain into separate namable parts.
[2]https://www.nitrc.org/projects/whs-sd-atlas

Hawrylycz et al. (2011)

Figure 2.1 visualizes the axes through origin of WHS in the brain of a rat. Within the scope of this project WHS will be the local space of the rat brain model implemented in Nevrolens.

Brain Atlas

A brain atlas is a composite representation based on one or more datasets of a given brain. An atlas generally has the function of highlighting some specified aspects and relations in the brain, and is a convectional tool in neuroscientific research (Toga and Thompson, 2000). The convectional atlas is based on micrometer scale sliced sections in the brain, effectively creating two-dimensional layers through the brain. While functional, this "turns the brain into a book". Three-dimensional digital atlas are however relative newcomer on the neuro-imagery scene, by employing magnetic resonance imaging (MRI) and diffusion tensor imaging (DTI) the resulting atlases are complete volumetric representation of the subject brain (Papp et al., 2014).
This volumetric model is the basis for the delineated 3D-model used in Nevrolens.

Sprague Dawley

Its a strain of laboratory rat.

2.4 Related work

HoloAnatomy

Insight Heart

SphenoBlock?

Noe HoloCare stuff?

Chapter 3

Implementation

3.1 Tools

Unity 3D

Mixed Reality Toolkit

Photon

Not in use jet

Blender

Git

Git flow, Gitmoji, GitKraken, Git gud

GitKraken Boards

Kanban and such
Used both / separately for Nevrolens and Project thesis.

3.2 Software Process

Incremental development etc. #agile

Where everything I learned in PU should shine!

3.3 Validation / Testing

Chapter 4

Results

Chapter 5

Conclusions, Discussion, and Recommendations for Further Work

5.1 Summary and Conclusions

5.2 Discussion

5.3 Recommendations for Further Work

- Collaboration, Networking
- Macro+micro implementation
- Importing new models
- Look into volumetric rendering

Appendix A

Acronyms

NTNU Norwegian University of Science and Technology

AR Augmented Reality

MR Mixed Reality

XR Extended Reality

VR Virtual Reality

HMD Head-mounted display

WHS Waxholm Space

GPU Graphics Processing Unit

SDK Software Development Kit

COVID-19 Coronavirus Disease 2019

MRI Magnetic Resonance Imaging

DTI Diffusion Tensor Imaging

Appendix B

What to put in appendixes

This is an example of an Appendix. You can write an Appendix in the same way as a chapter, with sections, subsections, and so on. An appendix may include list of code (in case you are programming), more details about results that you have presented in the report (could be a more complete description of results, in case you decided to focus on the most important ones in the main report), supplementary information and descriptions you have found relating to the system you are analysing, such as drawings. You may discuss with your supervisor what are relevant information for appendixes.

B.1 Introduction

B.1.1 More Details

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