NTNU
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A Serious Game for Medical Image Interpretation

Martin Schiller Tønnessen

Title: A Serious Game for Medical Image Interpretation

Student: Martin Schiller Tønnessen

Problem description:

The national competence center for ultrasound and image guided therapy was established in 1995 and is a collaboration between SINTEF, NTNU and St Olav. Within the center ultrasound-based navigation technology is being developed and used in various clinical fields in order to guide surgical instruments safely into the human body (similar to GPS navigation). One of the main challenges in order to make use of this technology is sufficient knowledge about interpreting ultrasound images. Each week unique data material is collected within the center. If presented in an easy and knowledgeable way, selected parts of the anonymous material can be used to teach relevant groups to interpret ultrasound images in an entertaining manner. A serious game has huge potential in this regard.

The possibilities are almost endless but some basic suggestions could be to learn ultrasound interpretations of brain images by presenting:

– Anatomy – The user sees an ultrasound image as well as names of anatomical structures and is challenged to drag each name onto the correct structure.

– Pathology – The user sees ultrasound images of varies tumors and is asked to identify the tumor and state the type (multiple choice).

– Tumor borders – Some tumor types have diffuse border to normal tissue. The user sees such images and is asked to draw the border.

An application should be developed that can incorporate different types of images and it should be easy to generate and upload new material and make it available. The application should have user profiles and a global scoreboard.

Responsible professor: Frank Lindseth, IDI

Supervisor: Frank Lindseth, IDI

Abstract

It is now quite common to use different types of image modalities such as ultrasound and MRI in the practise of medicine. However, the different modalities require experience and practice. A study of the potential behind the idea of a mobile application was made as a part of a master-thesis in the spring of 2015. The mobile application prototype, Nerve Blocker, was nearly finished. Later, in the fall, a pre-thesis project finished the application and evaluated its potential for covering other procedures. The project concluded that the application was not a good starting point for a generalized application, and suggested that a new web application would be a better solution.

The conclusion of the pre-thesis project has been evaluated and as suggested, the web application called Medical Imaging Interpretation Games has been developed. Through user testing, the application showed to be a promising tool for teaching different types of procedures using different image modalities.

A framework for adding content and creating solutions was also developed and implemented into the web application, making it possible to add new and remove existing content.

Sammendrag

Det er blitt ganske vanlig å bruke forskjellige typer bilde modaliteter som ultralyd og MRI innen medisin. For å kunne bruke slike bilde modaliteter må brukerne ha erfaring med å tolke bildene. En masteroppgave ble utført våren 2015 med et mål om å lage en mobilapplikasjon for å gi anestesistudenter muligheten til å tilegne seg erfaring innen tolkning av ultralyd bilder. Evaluering av applikasjonen viste at prototypen hadde et potensial til å bli et bra læringsverktøy for anestesistudenter. Prototypen ble ikke helt ferdig, men ble under høsten 2015 videreutviklet og evaluert med tanke på å utvide applikasjonen til å inneholde andre typer bilder i et forprosjekt. Konklusjonen til forprosjektet var at prototypen ikke egnet seg til å bli videreutviklet til å bli en generalisert versjon og foreslo i steden å utvikle en ny web applikasjon.

Konklusjonen fra forprosjektet er i denne masteroppgaven blitt evaluert og som foreslått er en web applikasjon under navnet Medical Imaging Interpretation Game er blitt utviklet. Brukertester har vist at applikasjonen har potensiale til å bli et verktøy for å lære forskjellige typer bildemodaliteter.

Et rammeverk for å legge til og lage løsninger til bilder og videoer har også blitt utviklet og implementert i web applikasjonen.

Preface

This thesis is the result of the work completed for my Master of Science and Technology degree in Computer Science at the Norwegian University of Science and Technology. The work was carried out during the spring semester of 2016, in collaboration with SINTEF and St. Olav's Hospital.

I would like to thank my supervisor, Dr. Frank Lindseth, Senior Researcher Scientist at SINTEF medical technology and Associate Professor at Computer and Information Science (IDI), who offered guidance, constructive critique and advice throughout this thesis. Next, I would like to thank Cecilie Våpenstad, SINTEF researcher and PhD student at NTNU, who offered creative ideas and guidance. I would also like to give my gratitude to the employees at SINTEF who participated in the user test.

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Acronyms

ADMC Apple Developer Member Center.

API Application Program Interface.

APK Android application package.

ASF Apache Software Foundation.

AVDM Android Virtual Devices Manager.

AWWDRCA Apple Worldwide Developer Relations Certification Authority.

CPT Cross-platform tools.

CSS Cascading Style Sheets.

CT Computed Tomography.

GUI Graphical User Interface.

HTML HyperText Markup Language.

IDC International Data Corporation.

IDE Integrated development environment.

JS JavaScript.

MIIG Medical Imaging Interpretation Game.

MRI Magnetic Resonance Imaging.

MVC Model View Controller.

NTNU Norwegian University of Science and Technology.

PHP PHP: Hypertext Preprocessor.

QML Qt Modelling Language.

RA Regional Anesthesia.

SDK Software Development Kit.

SINTEF The Foundation for Scientific and Industrial Research.

SUPR-Q Standardized User Experience Percentile Rank Questionnaire.

SUS System Usability Scale.

UDID Unique Device Identifier.

URL Uniform Resource Identifier.

Chapter 1

Introduction

1.1 Introduction

Within the practice of medicine, many tasks require a certain skill and experience to be done correctly. These are not always tasks that can be practised without a patient, which makes it harder to become proficient at it. One example of such tasks is a procedure called ultrasound-guided nerve blocks that provides anaesthesia of small part of the body. This allows the surgeon to do operations on limbs or regions of the body without using general anaesthesia, where the patient is put into a medically induced coma. To successfully perform this procedure, the anesthesiologist must have a proficient skill in ultrasound image interpretation. The anesthesiologist can, by guiding a needle inside the patient's body using real-time ultrasound images, create a regional anaesthesia.

Lack of skills and experience is often one of the main challenges when investing in new technology. Consequently, it is very beneficial to expose medical students to different technologies and allow them to practice in all the areas they wish to become proficient.

1.2 Problem definition

The national competence centre for ultrasound and image-guided therapy is a collaboration between three institutions in Trondheim, Norway: The Foundation for Scientific and Industrial Research (SINTEF), Norwegian University of Science and Technology (NTNU) and St Olav University Hospital. The centre works to improve current surgical methods and to develop new techniques for minimally invasive surgery, with a particular focus on ultrasound-guidance. Within the centre, unique ultrasound data is collected weekly.

The development of a prototype of a mobile game application that uses such data was nearly finished in the summer of 2015. The application's area of focus was

on the femoral nerve block, a specific regional anaesthesia procedure that provides anaesthesia for the anterior thigh, the knee, and the femur. The ultrasound data used was, therefore, femoral ultrasound images. The application, named Nerve Blocker, would teach the material in an entertaining manner, encouraging users to learn. In the fall of 2015, the prototype was further developed and tested in a pre-thesis project. Another project in the fall of 2015 improved and evaluated an application developed in 2014 where the focus area was neuro surgery. Both projects concluded that it would require much more work to make the application useful for other fields and that it would be better to create a new generalised web-based application.

The main target group for the application developed in this thesis is students and physicians training to become anesthesiologists, but the application should also be useful for students of other fields within medicine. The application may also be relevant to doctors who want to refresh their knowledge and other groups wishing to learn to interpret ultrasound images.

1.3   Thesis goals

The goal of this thesis is to develop a web application that can teach different types of image interpretation in an entertaining manner. The application should also incorporate a system for uploading and creating solutions for data.

1.4   Thesis limitations

This thesis will focus on developing a web application that can be used as a tool to teach the procedure called *peripheral nerve block*. The features of the application may be useful to teach other procedures such as appendectomy and ultrasound-guided neurosurgery, but they will not be described in this thesis.

<div align="right">

Chapter **2**

Background

</div>

Background

Developing an educational application requires an understanding of the users and the content to be able to present the content in the best way possible. The motivation behind developing this application was the medical procedure Regional Anesthesia (RA) and ultrasound guided neuro surgery. To be able to teach others about RA it is important to have thorough understanding of the topic. In section 2.1.2, RA is explained with focus on the femoral nerve block technique.

Later, in the section 2.2, some theories about how to make a serious and educational game is presented. Section 2.4 will evaluate the users and their needs while the last section 2.5 will cover related work. Parts of the background are obtained from previous work[1].

2.1 Ultrasound-guided regional anaesthesia

In this section, the basics of ultrasound imaging are explained as well as their use in RA. Finally, the procedure for blocking the femoral nerve is explained and how it is taught in teaching institutions.

2.1.1 Ultrasound imaging

Ultrasound imaging uses high-frequency sound waves to view the inside the body. Ultrasound images are captured in real-time. Therefore, they can also show the movement of the body's internal organs and blood flowing through the blood vessels. Compared to X-ray imaging, there is no ionising radiation exposure associated with ultrasound imaging, and it is considered as safe when used prudently by appropriately trained personnel.

In an ultrasound exam, the transducer (probe) is either placed directly on the skin or inside a body opening. To eliminate air pockets that may block the ultrasound from passing into the body a thin layer of water-based gel is applied to the skin.

Figure 2.1: Picture of a transducer (probe) used during an ultrasound exam. [2]

Ultrasound images are produced based on the reflection of waves when they hit body structures. Both the strength (amplitude) of the signal and the time it takes to return to the transducer provide the information necessary to produce an image.
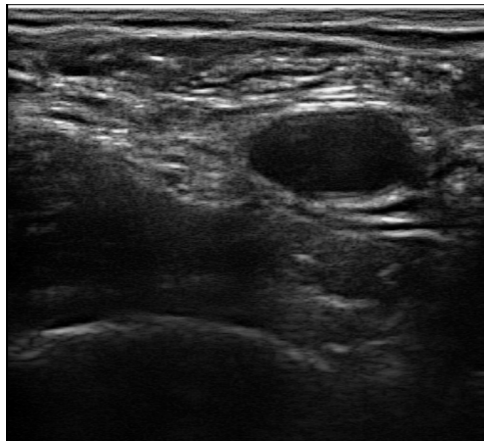
Figure 2.2: Example an ultrasound image.

2.1.2   Regional anesthesia

In general anaesthesia, you are unconscious and have no awareness or other sensations. In RA, your anesthesiologist makes an injection near a cluster of nerves to numb the area of your body that requires surgery.

The term RA is often used to indicate that a relatively large part of the body is anaesthetized, i.e. the hand, the lower leg, or an entire arm.
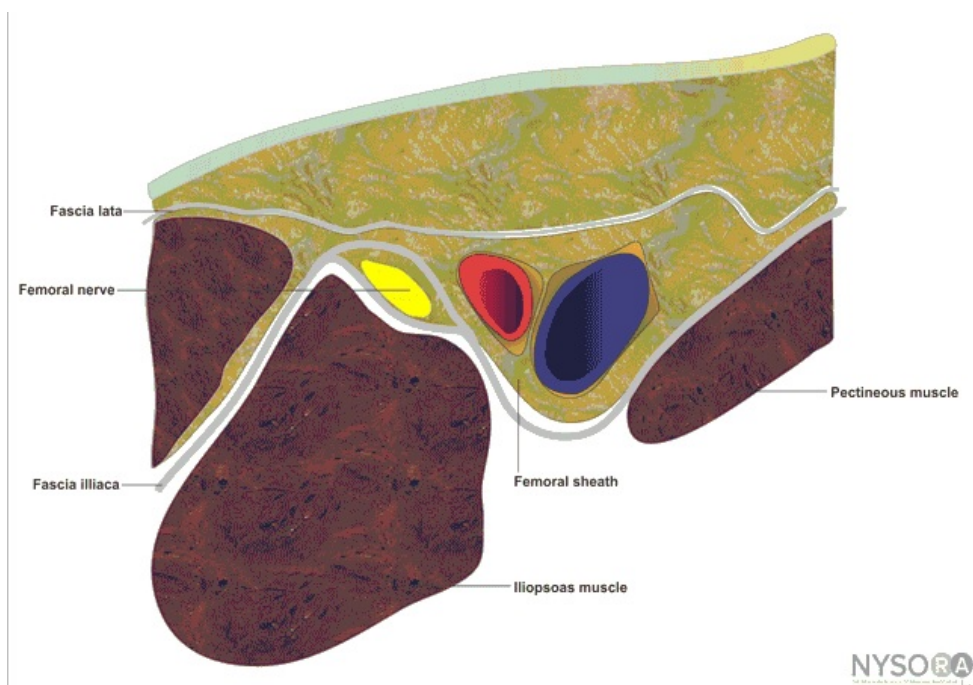
Figure 2.3: A cross-section of the upper thigh illustrating the anatomy of, and around, the femoral nerve.

When performing RA on a limb, it is common to use a procedure called *peripheral nerve block*. An example of the peripheral nerve block is axillary nerve block. Illustrated in the figures 2.4a and 2.4b, ultrasound is used to find the nerve and guide the needle to the right place for injection.

The use of ultrasound-guided nerve blocks has gained popularity the recent years due to their advantages of "improving patient safety and interventional anaesthesia efficacy"[3]. The ultrasound transducer acquires real-time images of the needle insertion, which is the reason ultrasound is chosen over any other imaging modality for this procedure.

2.1.3   Teaching ultrasound-guided femoral nerve block

In Hadzic's textbook on regional anaesthesia and acute pain management[4] he describes the process of learning how to perform ultrasound-guided regional anesthesia as follows:
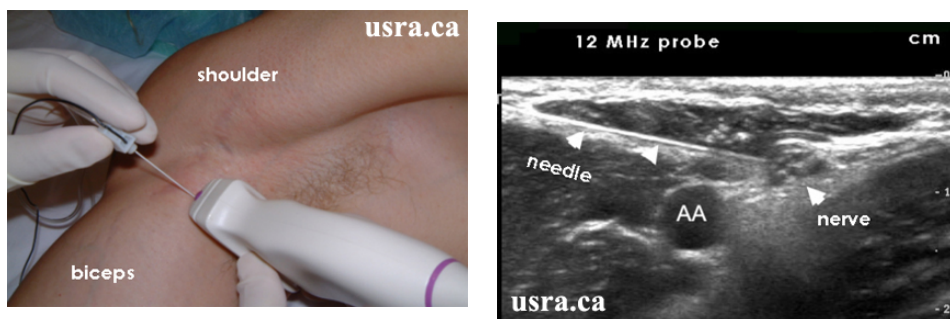
(a) The needle is placed inline with and parallel to the transducer.

(b) Needle can be followed in real time.

Figure 2.4: Illustrations of ultrasound guidance to perform a nerve block

«Several steps are critical in achieving proficiency with ultrasound imaging for the regional block. The first step is scanning skills (the ability to obtain images and recognise nerves). Scanning practice and review of teaching files are critical. [5]»

The term "scanning skills" here mean the process of positioning the ultrasound transducer correctly, to display the anatomical structures best possible. The operator must have full control of the anatomical structures before continuing with the procedure.

2.2   Gamification

The process of making systems, services and activities more enjoyable and motivating is referred to as gamification. The basic idea is to turn material that usually requires the user to read or study, into a game where the user learns and understands the material while having fun.

A paper written by Thomas W. Malone named 'what makes things fun to learn? - Heuristics for designing instructional computer games'[6] explains what a computer game need to be fun. He organizes the answer to what makes things fun to learn into three major categories: challenge, fantasy and curiosity.

The paper discusses both intrinsic motivation, performing an action because you enjoy the activity itself, and extrinsic motivation, behaviour that is driven by external rewards. Simply put, intrinsic motivation originates inside of the individual while extrinsic motivation arises from outside the individual.

2.2.1 Challenge

The importance of challenge can be derived from the studies of intrinsic motivating activities. Csikszentmihalyi's analysis, mentioned in Malone's paper[6], gives the following description of intrinsically motivating activities:

1. The activity should be structured so that the level of challenges can be increased/decreased in order to match the player's skills

2. It should be easy to isolate the activity.

3. There should be clear criteria for performance; it should be easy to evaluate how well or how poorly one is doing at any time.

4. The activity should provide concrete feedback to the actor on the actors performance.

5. The activity ought to have a broad range of challenges.

All of these, except number 2, involve ways of making an activity challenging. While the analysis is useful, it only gives a little idea of why these features are important.

Numerous writers have noted that for an environment to be challenging, it must provide *goals* whose attainment is uncertain. Malones paper[6] suggests the following ideas to provide an appropriate goal:

– Simple games should provide an obvious and compelling goal.

– Users should easily be able to pick the appropriate difficulty.

– The best goals are often practical or fantasy goals rather than goals of using a skill.

– Players must be able to tell whether they are getting closer to the goal or not.

An uncertain outcome is essential to keep the player entertained. In the paper, Malone suggests four ways to make the outcome of a game uncertain.

– Variable difficulty level.

   Determined automatically by the program

   Chosen by the player

   Determined by the opponent's skill

– Multilevel goals. Games often have several levels, and within each level, there can be different goals.

Score-keeping. With this feature, the meta-goal is to get as high(or as low) a score as possible.

Speeded responses. The meta-goal is to do the task as fast as possible.

– Hidden information

– Randomness

2.2.2   Fantasy

Fantasy can be used to make the instructional environment more interesting and more educational. Malone defines a fantasy-including environment as one that evokes "mental images of things not present to the senses or within the actual experience of the person involved".

The fantasy aspect of a game can be divided into two parts, extrinsic and intrinsic fantasy. An extrinsic fantasy depends on the skill of the player and whether or not it is used correctly. In intrinsic fantasy, on the other hand, the player's skill also depend on the fantasy.

2.2.3   Curiosity

The curiosity of the player should be evoked by providing an optimal level of informational complexity. Malone states that in general, an optimally complex environment will be one where the player knows enough to have expectations about what will happen, but where these expectations are sometimes unmet. Malone distinguishes between two kinds of curiosity; sensory curiosity and cognitive curiosity.

Sensory curiosity can be invoked by making attention-attracting changes such as changing the lighting, sound or other sensory stimuli of an environment. By making such changes the player becomes curious to what is going to happen.

Cognitive curiosity can be evoked by the prospect of modifying higher level cognitive structures. Malone's theory is that people are motivated to bring all three of their cognitive structures of the characteristics of well-formed scientific theories: *completeness*, *consistency*, and *parsimony*. According to this theory, the player are motivated to learn more when their existing knowledge seem incomplete, inconsistent or un-parsimonious.

2.2.4   Serious games

The expression "serious game" appeared long before the computer technology we have today. In the 1970s Clark Abt discussed the idea and used the term in his book "Serious Games"[7]. In the book, his references were primary to the use of board or card games, but the definition is still considered applicable in the computer age.

Mike Zyda provided an updated and logical approach to the term in his article from 2005 in the IEEE Computer magazine [8] titled "From Visual Simulation to Virtual Reality to Games"[9]. Zyda's definition is as follows:

– Game: "a physical or mental contest, played according to specific rules, with the goal of amusing or rewarding the participant."

– Video Game: "a mental contest, played with a computer according to certain rules for amusement, recreation, or winning a stake."

– Serious Game: "a mental contest, played with a computer in accordance with specific rules that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives."

2.3   How we remember what we see

In 1970 Scientific American magazine published Ralph Haber's research[10] on individuals recognition accuracy of images.

> We associate and remember images because they make use of a massive range of cortical skills, especially imagination. Images can be more evocative than words, more precise and potent in triggering a wide range of associations, thereby enhancing creative thinking and memory.

An article in *The Malaysian journal of MedicalSciences* named *The Influence of Colour on Memory Performance: A Review* [11] presents the relationship between colours, attention and memory performance. A quote from the article states that:

> Colour has been found to influence memory performance by increasing our attentional level and arousal. There exist robust evidences from several studies that have been conducted to explore the relationship between colour and memory performance.

Most skills requires memory of similar situations to know how to proceed. For example, as mentioned in section 2.1.3, the scanning skills is the skill of placing the

ultrasound transducer correctly using live ultrasound images. The operator gets better by recognizing anatomy and moving the transducer to get the best possible view-point.

2.4   Users

Jakob's Law of the Internet User Experience[12] states that users spend most of their time on *other* sites. Which means that users expect that a site works the same way as other sites. This is mostly in regard to controls and standardized design such as blue text links and shopping cart icons.

Consistency is another important factor for users. Inconsistency can easily confuse users and reduce the user experience of the site. A simple rule is "the same name for the same thing in the same place" makes things easy.

The audience of an application is a deciding factor of how the application is designed. This web application will have users in a wide age-range and with different background and educations i.e, one user may be a student in their twenties, while another may be a doctor in their fifties.

The audience for this application can be divided into three types; *players*, *content holders* and *experts*.

– Content holders

   The content holders are the technicians working equipment and store the data. They are usually not experts on the data collected, but they have access to the data. If made available, this data can be used by experts to create tasks for the players.

– Experts and teachers

   Teachers and experts either have their own content, or they can create solutions for content uploaded by others.

– Students/players

   The players will typically be medical students who want to learn or doctors who want to refresh their knowledge.

2.5   Related work

In the spring of 2015 a prototype of a mobile application[13] with the goal of teaching femoral ultrasound interpretation was developed. Later, in the fall of 2015, a project with the goal of finishing the prototype and releasing it to the different stores,

discussed the application prototype's future with regard to covering other areas within medicine.

> Future development of the application can be done in two ways, either keep the application as it is, but improve it, or create a generalized version that covers more than just RA.

The prototype was developed using Qt as Cross-platform tools (CPT), and the project concluded that the complexity of merging and expanding the source-code in Qt would require a lot of work. The suggested solution was to develop a generalized web-based application.

A tool for establishing a solution for the content was an important element that was missing from the prototype. The project discussed different ways of doing this, and concluded that the best approach for creating solutions would be to use the average from multiple solutions proposals.

> Establishing a solution for the images is also an important aspect of the generalized application. The best way to create solutions would be to use the average of multiple solution proposals by experts.

2.5.1   Feedback

Both the thesis in the spring[13] and the project in the fall had received feedback from testers. Most of the constrictive feedback were related directly to the application's layout, and the overall impression was that it could be a good tool for learning medical image interpretation.

The users who tested the mobile prototype was asked to fill out a SUS. The results of the user tests are shown in the figure 2.5. The application scored 85,25 points out of 100, which corresponds to the rating "excellent" using the Adjective Rating Scale shown in figure 2.6.

#	Question	Avg	Score
1	I think that I would like to use this system frequently	3,5	2,5
2	I found the system unnecessarily complex	1,5	3,5
3	I thought the system was easy to use	4,6	3,6
4	I think that I would need the support of a technical person to be able to use this system	1,1	3,9
5	I found the various functions in this system were well integrated	4,3	3,3
6	I thought there was too much inconsistency in this system	1,3	3,7
7	I would imagine that most people would learn to use this system very quickly	4,1	3,7
8	I found the system very cumbersome to use	1,3	3,7
9	I felt very confident using the system	4,2	3,1
10	I needed to learn a lot of things before I could get going with this system	1,8	3,1
		SUS score	**85,25**

Figure 2.5: Feedback on the mobile prototype
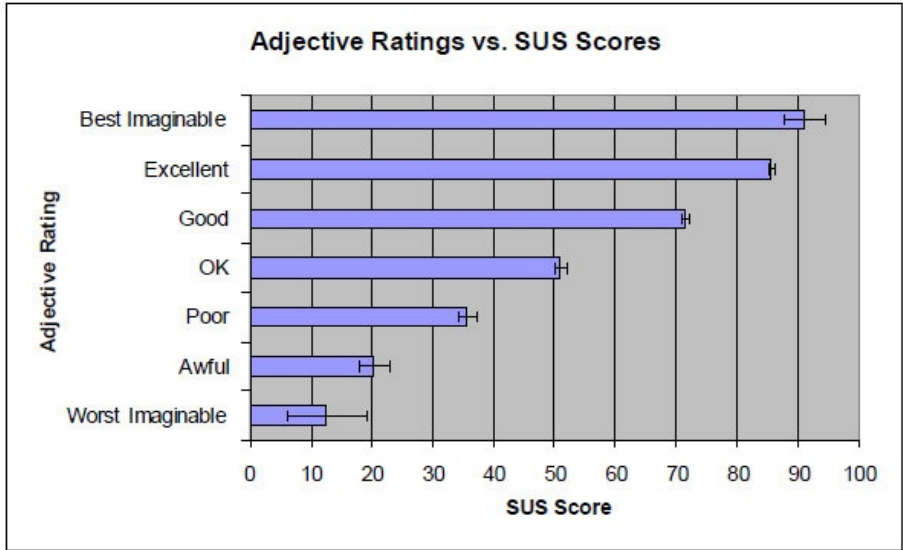
Figure 2.6: The Adjective Rating Scale of a SUS

2.6   Existing solutions

An enormous number of serious games use simulation to convey information to their user. Unfortunately, there is not enough documentation for most of these games. In this section, some games with similarities to this project will be looked into.

2.6.1   A Serious Game for Learning Ultrasound-Guided Needle Placement Skills

In 2012, a thesis describing the development and evaluation of a game targeted towards future intervention radiologists was published with the title "A Serious Game for Learning Ultrasound-Guided Needle Placement Skills"[14]. The thesis developed a serious game to teach the skills of needle placement in procedures such as biopsy, local anesthesia, and fluid drainage.

The game contains a virtual reality-based surgical simulator where the player communicates with 3D objects in a virtual world. The player manipulates surgical tools in 3D space with a 6-DOF haptic device (needle) and a 6-DOF tracker (transducter) which gives the game a high degree of realism. The game contains many different elements such as time-attack tasks, realistic modelling, Similar to this thesis, the game has the same type of audience and objective of the game. However, the game requires specialized hardware, and it is uncertain whether or not the game is released anywhere.
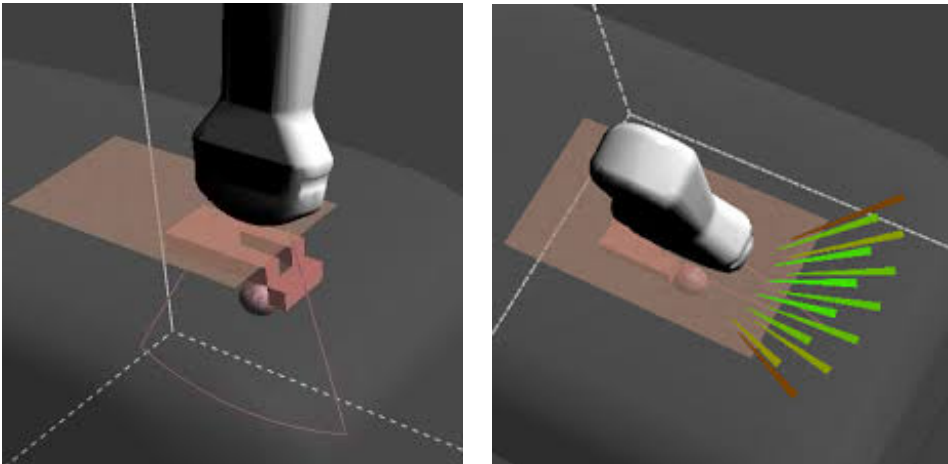
Figure 2.7: Game component of ultrasound-guided needle placement skills

2.6.2   Virtual Deep Brain Surgery

Virtual Deep Brain Surgery game [15] is a science game where the player can play all steps before and after surgery of a patient with a movement disorder or Parkinson's disease. The player plays three out of five steps through the treatment process: evaluating a patient, putting fiducial, performing brain surgery, putting the battery, activating the battery and finally set the system. Each step has a quiz that pops up and asks the player related theoretical questions that a neurosurgeon should know. As a player, one get a good overview of a neurosurgeon, but it does not give any exceptions that may happen during the surgery, which may give the player a too optimistic impression of the operation.

2.6.3   LAP Mentor

The LAP Mentor [16] is a multi-disciplinary surgical simulator that was developed in close collaboration with the medical community to provide a meaningful and valuable training solution. It has a comprehensive library of modules that give the users the option to train anything from basic tasks and skills to advanced complete procedures.

It is somewhat similar to the game mentioned in section 2.6.1, "A Serious Game for Learning Ultrasound-Guided Needle Placement Skills". It is a virtual reality-based surgical tool where the user operates the tools in the same way as one would in a real surgery. It requires specialized hardware and is quite large as seen in figure 2.8.
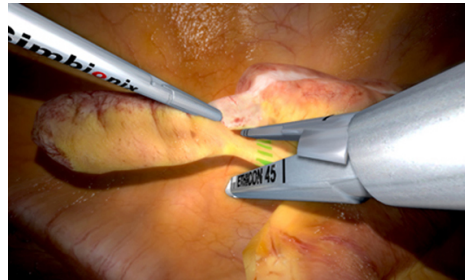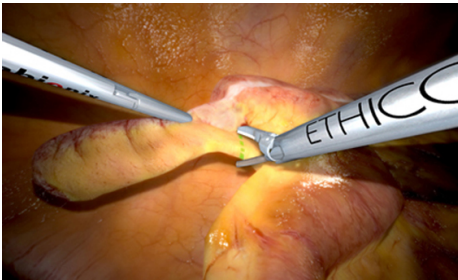
(a) View of the appendix and a energy tool

(b) View of appendix and the stapler tool

Figure 2.8: Appendectomy module of the LAP Mentor

Chapter 3

Methodology

In this chapter the methodology used for developing an application is presented. The first section, 3.1, presents different alternatives to creating the application and the alternative chosen. The section 3.2 presents different ways of making an application mobile-friendly, and section 3.3 presents the functional and non-functional requirements of the application. Section 3.4 covers the development process of the application, and the last section 3.6 presents different evaluation methods and how it will be done in this application.

3.1 Platform

The application was originally intended for mobile devices only. With a web application both mobile and desktop users can use it. The conclusion mentioned in section 2.5 suggests developing a web application. In this section, this conclusion shall be evaluated to decide if it is the best approach.

The best way to establish good solutions will be using a desktop, mainly because of it is easier to create accurate solutions using a mouse compared to using a mobile touch-screen. A mobile application is still a choice as long as the application for solution creation is kept separate and for desktop only.

3.1.1 Different ways of developing the application

Deciding whether to develop a web or native application is a fundamental decision that needs to be made right away, and that will play a crucial role in the long-term success of the endeavour. Before choosing the platform for a project, it is important to evaluate the project and its audience. As mentioned in the section 2.4, the players and the primary audience will be students. Practically all students nowadays have both laptops and smartphones.

Native and cross-platform applications

Developing a native application is sometimes the best solution, but not always. Native applications tend to be faster and more responsive because the code that runs the application is stored on the device, there is no time spent waiting on static content to be downloaded. This approach gives the developer direct access to the platform's hardware features, allowing interesting functionalities such as accessing GPS information, making phone calls, etc. The biggest drawback of developing native applications is that a separate code base must be created and maintained for each platform.

This drawback can be avoided by developing the application using a cross-platform tool, but the developer still has to compile the application for the given platform and maintain it in the different stores.

Web application development

A web application is an application that can be accessed by the users through a Web browser. The browser creates Hypertext Transfer Protocols (HTTPs) requests for specific Uniform Resource Identifiers (URLs) that map to resources on a Web server. The server renders and returns HyperText Markup Language (HTML) pages to the client, which the browser can display. Developing a web application requires knowledge of HTML, Cascading Style Sheets (CSS), JavaScript (JS) and usually some libraries. The biggest upside of a Web-based approach is, of course, the biggest downside of a native one. The code base will be singular, and the application will be usable on computers as well as any device with a web-browser. A developer can make real-time changes to the application, i.e., no waiting for the app stores to approve the changes and the users does not have to update the application. However, the application needs to be optimised for both desktop and mobile devices.

The biggest downside of a web application is the limited access to hardware features of a mobile device. From a technical perspective, the web technology is moving quickly forward, and most of these limitations can be compensated for or overcome entirely[17].

Evaluation of approaches

An important factor to consider is the tool for solution creation. As mentioned, a desktop application is the only viable way for creating solutions. The alternatives are to make one web application or two applications, one for desktop and one for mobile devices. The latter would require a lot of extra work, which would be too time-consuming for this thesis. Therefore, the application will be a web application that works on both desktop and mobile devices.

3.2 Mobile-friendly development

A web application is expected to work on both desktops and mobile devices, and this can be achieved without any special modifications. But a web application developed with only desktops in mind would not look as good on a mobile device.

There are many ways to make a web application look good on both desktop and mobile devices. The two obvious ones are either create a separate mobile site, as seen on many websites today or set the stylesheet based on the device used. The best option for this thesis is to use a different stylesheet based on the device.

Aside from using different stylesheets there are a some small adjustments that can be made to make an application more mobile-friendly. In this section some of these adjustments will be explained.

3.2.1 Form input attributes

Making typos on mobile devices with a touch-screen is easy. Therefore most devices come with a built-in dictionary to auto-correct. Problems may arise when typing names, addresses, etc. A simple way to avoid this is to turn off auto-correct on such fields. It may also be appropriate to set auto-capitalize on words in name fields. This will save the users from having to toggle the capslock key for each successive name.

```
What's your name:
<input type=text size=20 autocorrect=off autocapitalize=
    ↪ words>
```

To make email typing easier for the user, one can set the field-type to email so that the user gets presented with the @ key without needing to switch to the numeric/symbol keyboard.

```
What's your email: <input type=email size=20>
```

To avoid that text-fields goes outside the window of the screen one can set the max-width to 100% in the CSS stylesheet.

```
input, textarea {
  max−width:100\%
}
```

3.2.2 Mobile-friendly preferred width

The width of a website is usually not a problem on desktop browsers, but mobile devices are usually quite narrow. By finding the minimum width needed for the

website to be readable and setting it as the preferred viewport will force mobile devices to use this width.

```
<meta name=viewport content='width=700'>
```

3.2.3   Avoiding *fixed* positioning

Using *fixed* positioning may cause e.g the header to obscure the whole screen if the user zoom in. This can be avoided by using static positioning on devices with narrow screens.

```
<style>
/* regular css */
#header {
  position: fixed
}

@media screen and (max-width: 500px) {
/* applies only if the screen is narrower than 500px */
  #header {
    position: static
  }
}
</style>
```

3.2.4   Javascript and jQuery

Some scripts and function need to be specialized for the given platform, this can be achieved by checking the userAgent's navigator and executing the fitting code. A basic example is shown below.

```
if (/Android|webOS|iPhone|iPad|iPod|BlackBerry/i.test(
    ↪ navigator.userAgent)) {
} else {
}
```

3.3   Application requirements

The application's functional and non-functional requirements are presented in table 3.1 and 3.2 respectively.

Functional requirements describes numerous features the application is expected to have, their difficulty to implement and the priority of the given requirement.

Non-functional requirements describes desired qualities of the application, i.e. usability, platform compatibility and stability.

3.3.1   Functional requirements

Table 3.1: List of the Functional Requirements

#	Functional Requirement	Complexity	Priority
FR1	Three different game modes	High	High
FR1.1	Outline	Medium	High
FR1.2	Landmark and outline	Medium	High
FR1.3	Video	High	High
FR2	The game modes should have the difficulty-options easy, normal and competitive	Medium	Medium
FR2.1	Easy should display the solution to the task	Low	Medium
FR2.2	Normal should not display the solution until the answer has been submitted	Low	Medium
FR2.3.1	Competitive should have a time constraint	Medium	Medium
FR2.3.2	Competitive should have a scoring system that is displayed in the difficulty selection	High	Low
FR2.3.2	Correct answer in competitive should give bonus-time	High	Low
FR3	In the video game mode, the player should locate a correct spot for the given task	Medium	High
FR4	There should be an option for adding textual questions to images	High	Low
FR5	It should be possible to upload new content	High	High
FR5.1	Uploading and creating solutions for images	High	High
FR5.2	Uploading and creating solutions for videos	High	Medium

FR6	There should be an admin-interface for administrators	Medium	Low
FR6.1	It should be possible to manage content, disable/edit/delete images and videos	High	Low
FR6.2	It should be possible to manage users and their access-level.	High	Low
FR7	There should be a private game mode where users may upload content	High	Low
FR7.1	The private game mode should have the same difficulty options as regular game modes	High	Low
FR8	The application should have a scoring system with high-scores	Medium	High
FR8.1	The scoreboard should be visible in the given game mode menu	Medium	Medium
FR8.2	It should be possible to click on user-names to visit their profile	Low	Low
FR9	Each user should have their own profile	Medium	Low
FR9.1	The user profiles should show affiliation, name, etc.	Medium	Low
FR9.2	The profile should have a profile image uploaded by the user	Medium	Low

Functional requirements specified with the tag low-priority *is requirements with lower importance than the others. This means that these requirements are not necessary for the game to function properly.*

3.3.2   Non-Functional Requirements

Table 3.2: List of the non-Functional Requirements

#	Non-Functional Requirement	Priority
NFR1	The application should be easy to use	High
NFR2	The game should be fun to play	High
NFR3	The application should have a pleasing design	Medium
NFR4	The user should not require knowledge of the different topics to use the game	Medium
NFR5	The game should be educational and challenging for any user	Medium

3.4   Development process

The development process of a project is important, especially if there are many programmers. This project only had one programmer, which reduces the number of development processes that can be beneficial. The thesis "No Silver Bullet" by Fredrick Brooks [18] is about development processes, and why they often fail. Software development project succeeds when the key people on the team share a common vision. With only one programmer it is important that the customer/supervisor and the programmer has the same vision. Meetings early in the process will help make sure that the developer and the supervisor share the same vision.

The development process of this project has been following a form of the Extreme Programming (XP) software development methodology. XP is a type of agile software development form, which is intended to improve productivity. The methodology has four basic activities that are performed within the software development process: coding, testing, listening and designing.

– Coding

    The one truly important product of the system development process is code. Most of the time shall be spent on coding.

– Testing

    If a little testing can eliminate a few flaws, then a lot of testing can eliminate many more flaws. Unit tests determine whether a feature works as intended, while acceptance tests verify that the requirements as understood by the developer satisfy the customer's requirements.

– Listening

> The needs of the customer must be understood well enough to give the customer feedback about the technical aspects of how the problem can be solved.

– Designing

> To avoid that the system becomes too complex and the dependencies within the system cease to be clear one can create a design structure that organises the logic of the system.

A rough plan using a Gantt chart [19], with activities based on the XP methodology, is shown in the figure 4.9.

ID	Task	Start	Finish	Duration	Jan 2016	Feb 2016	Mar 2016
1	Initial meeting – defining project goal	11-01-16	11-01-16	2h			
2	Initial planning	11-01-16	22-01-16	10d			
3	Meeting	25-01-16	25-01-16	2h			
4	Requirement planning	25-01-16	05-02-16	10d			
5	Initial development – login and gameplay design	08-02-16	19-02-16	10d			
6	Meeting	22-02-16	22-02-16	3h			
7	Development – design and functionality improvements	22-02-16	01-04-16	29d			
8	Meeting	07-03-16	07-03-16	2h			
9	Meeting	04-04-16	04-04-16	2h			
10	Development – admin-interface, solution creation and upload functionality	04-04-16	13-05-16	29d			
11	Development – minor changes to prepare for alphatesting	02-05-16	19-05-16	14d			
12	Meeting	18-04-16	18-04-16	2h			
13	Meeting	02-05-16	02-05-16	2h			
14	Development – documentation	20-05-16	27-05-16	6d			
15	Alpha-testing active	16-05-16	03-06-16	14d 4h			
16	Meeting	30-05-16	30-05-16	2h			
17	Development – modifications based on feedback from test-phase	30-05-16	10-06-16	9d 4h			

Figure 3.1: Project schedule estimate

3.5   Architecture

The architecture of this web application will be a three-tier architecture style. A three-tier architecture has three layers: Presentation Tier, Application Tier and Data Access Tier. As shown in figure 3.2.
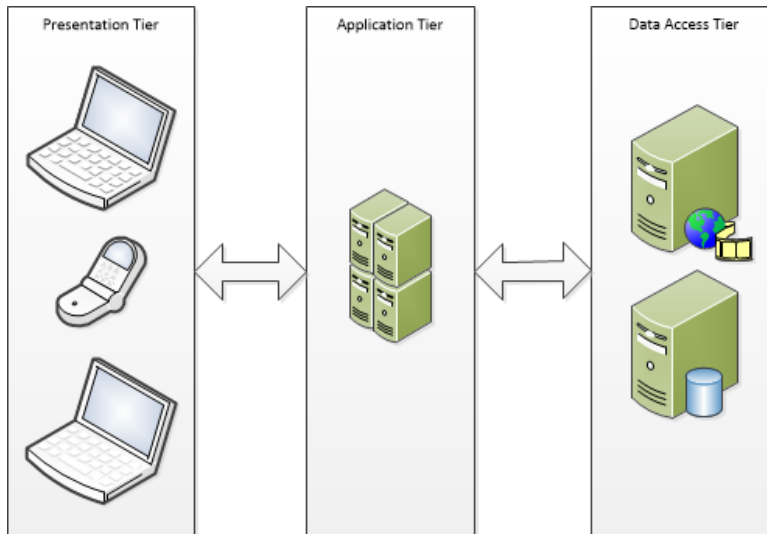

Figure 3.2: The three-tier architecture

3.5.1   Model–view–controller

The Model View Controller (MVC) architecture pattern, shown in figure 3.3, was used to make the application organised and easy to maintain. By using this pattern, the application is divided into three interconnected parts. The user uses the controller to manipulate the model, which in turn updated the view that the user see. In this project, the website is the view, the buttons are the controllers, and the database is the model. When a user uses the controller, here in the form of a button, the view is updated based on the controllers manipulation of the model.
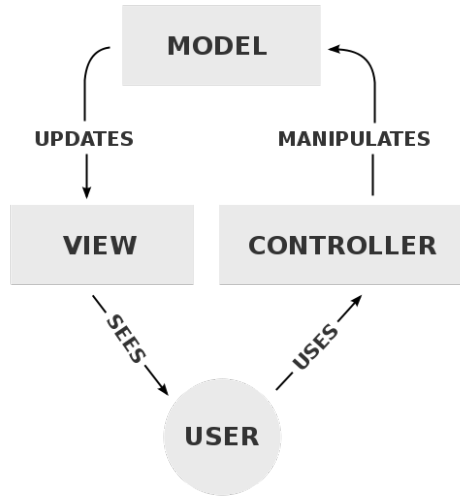
Figure 3.3: A typical collaboration of the MVC components

This pattern in combination with a three-tier architecture gives the design shown in the figure 3.4.
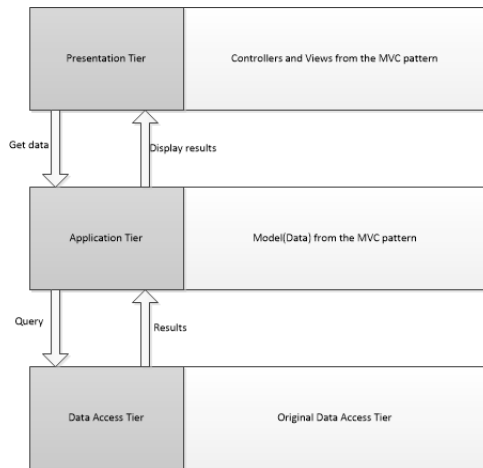
Figure 3.4: The combination of MVC and three-tier architecture.

3.5.2 Data flow

The data flow of a system can be illustrated using data flow diagrams (DFD). DFD's illustrates how data is processed by a system regarding inputs and outputs. To

simplify the DFD of this system the game and administration part are separated.

Figure 3.5 shows the DFD of the applications game-part, while the figure 3.6 shows the DFD of the administration part. The figure 3.7 explains the different symbols/figures in the DFD's.

Figure 3.5: Dataflow of the game

Figure 3.6: Dataflow of the admin-part

Figure 3.7: Symbol explanation of DFD

3.6 Evaluation

This section will present different ways of evaluating the application to assess its usability. It is also of interest to know if the design of the application is a good way for teaching different image interpretation methods.
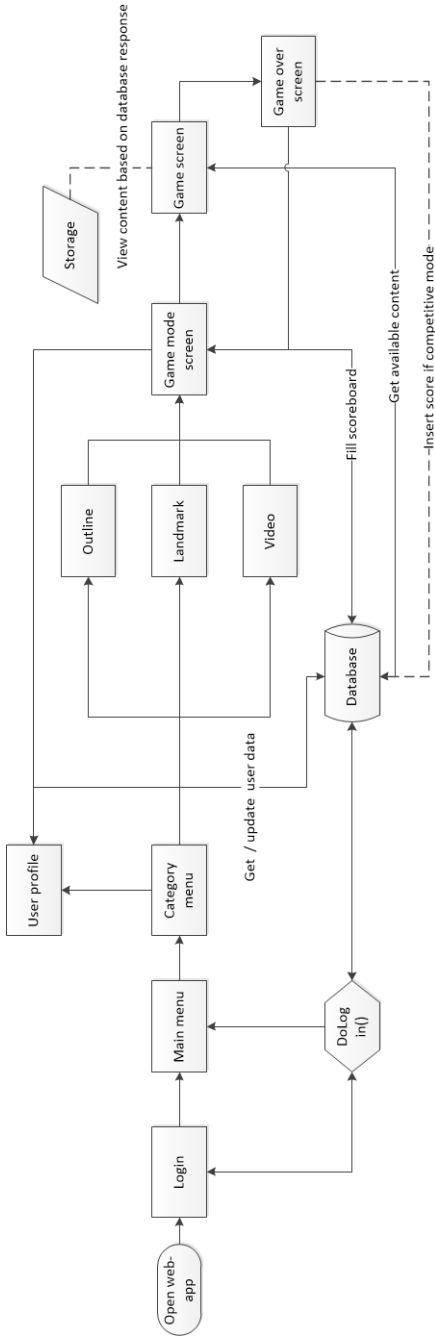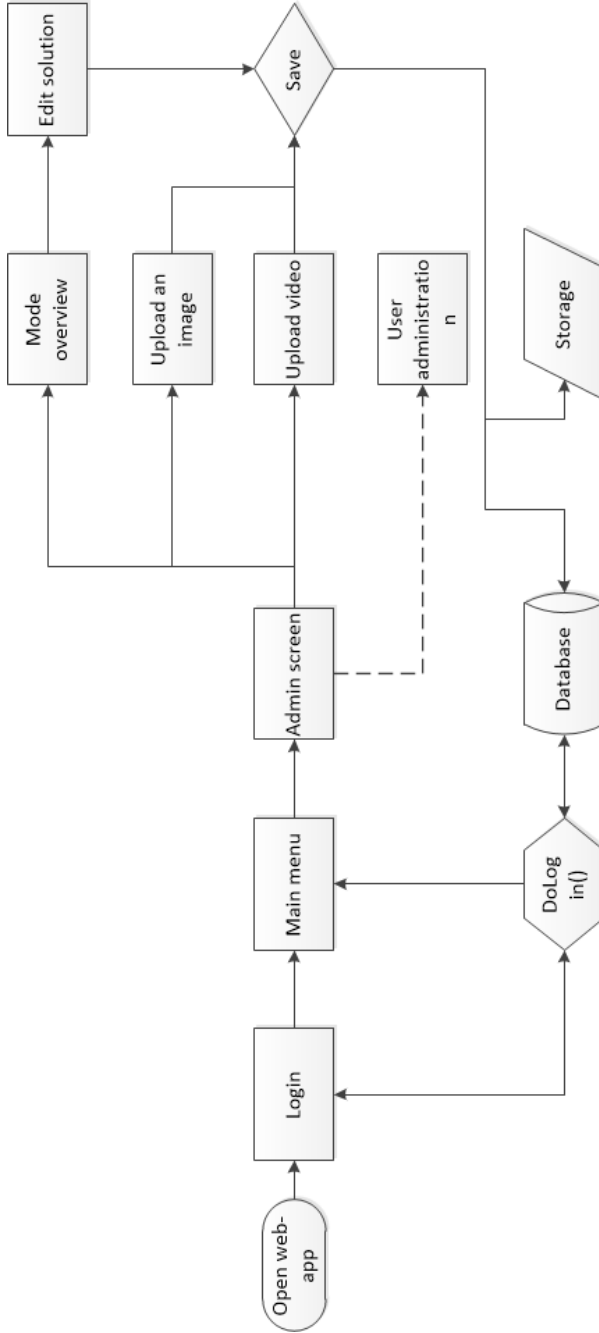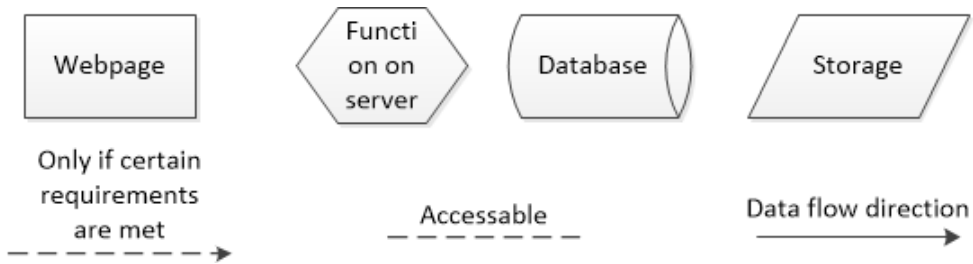
3.6.1 System Usability Scale (SUS)

SUS was invented by John Brooke who, in 1986, created this 'quick and dirty' usability scale as a tool to be used in usability engineering of electronic office systems [20]. The SUS has been tried and tested throughout almost 30 years of use. And it has proven itself to be a dependable method of evaluating the usability of systems compared to industry standards. It measures the usability of several different aspects:

- Effectiveness

    Can users successfully achieve their objective

- Efficiency

    Effort needed to achieve these objectives

- Satisfaction

    Was the experience satisfactory

An advantage of using SUS is that it is capable of handling small sample sizes (number of participants) and output a reliable result. Participants rank each question from 1 to 5 based on how much they agree with the statement. Five means they agree completely, and one means they disagree vehemently. Every question has a scale from 1 to 5. The score contribution for questions with an odd number is the scale minus 1 and for questions with even it is five minus the scale. The total score is calculated by summing of the score contribution of each question and multiplying it with 100 divided by the maximal achievable. The total score is defined from a range

of 0 to 100. The average System Usability Scale score is 68. If the score is under 68, then there are probably serious problems with the system usability.

3.6.2 Standardized User Experience Percentile Rank Questionnaire

The SUPR-Q [21] is a Rating Scale to Measure perceptions of Usability, Trust, Credibility, Appearance and Loyalty for Websites.

The questions of a SUS are generic enough to allow it to be used for a variety of applications. However, some questions do not fit well with websites. While SUS provides a reliable picture of users' attitudes toward usability, it excludes other important factors such as trust, credibility and loyalty.

> The SUPR-Q overall score has a strong correlation with a SUS score, r = .87, p < .001, meaning just four questions account for 87 percent of the variation in SUS (.87 squared). These questions are a good substitute for SUS on websites. [21]

A SUPR-Q licence is needed to be able to compare scores with lots of other websites. This license costs $1999 and is not considered to be worth it for this application, but the score itself can be used to evaluate the site and compare it to the few scores that are public. Optimally the scores should be compared to sites that are of the same type, but that is not possible without a license. An example of the SUPR-Q questions is shown in the figure 3.8.

Please rate your level of agreement to the following statements about the Amazon website.

	Strongly Disagree 1	2	3	4	Strongly Agree 5
I will likely return to the Amazon website in the future.	○	○	○	○	○
It is easy to navigate within the Amazon website.	○	○	○	○	○
The information on the Amazon website is credible.	○	○	○	○	○
I find the Amazon website to be attractive.	○	○	○	○	○
The information on the Amazon website is trustworthy.	○	○	○	○	○
The Amazon website has a clean and simple presentation.	○	○	○	○	○
The Amazon website is easy to use.	○	○	○	○	○

Figure 3.8: An example of the SUPR-Q questions

3.6.3   Chosen evaluation form

The concept of the SUPR-Q is good, and very useful for websites. The trustworthiness and credibility of a website are important. Therefore a modified version of the SUS with some of the questions used in a SUPR-Q will be used in the evaluation of this application. There will be 12 questions, which gives the following way of calculating the total SUS score:

For each odd question:
$$Score = (Avg - 1) \tag{3.1}$$

And for each even question:
$$Score = (5 - Avg) \tag{3.2}$$

Which gives the SUS$_{\text{score}}$ equation:

$$SUS_{score} = (5 - Avg_{score}) * 100/(12 * 4) \tag{3.3}$$

The form also contains a field where it is possible to leave textual feedback. This field is mainly for users who have comments on features and suggestions to improve the application.

Chapter 4

Implementation and game design

In this chapter, the implementation of the web application named Medical Imaging Interpretation Game (MIIG) is described. The application can be divided into two; game and administrator interface. First the login part of the application will be presented. Later, the section 4.2 presents the design of the game and the different game modes of the application. The administration interface is described in section 4.4, with details about uploading and solution creation. Section 4.5 will present the database configuration, and the section 4.6 will go through the functional requirements of the application and whether or not they have been fulfilled.

The application was first hosted on a private server, and later moved to a server at NTNU under the address http://miig.idi.ntnu.no.

4.1 Login

Creating a login feature is nothing new, so the best option here is to use some open-source login feature. Panique [22] has created a good login-feature using PHP: Hypertext Preprocessor (PHP) that is under the MIT Licence [23]. It handles both registrations, with e-mail verification and log-in. The security of the feature is quite good as it uses PHP 5.5's password_hash() function to hash passwords, and sha256 to create cookies.

4.2 Game modes

The three game modes are similar in some ways. All of them need a paint event handler that handles the click/touches on the overlay that is on top of the game canvas. The users interact with an overlay in all three game modes, and the solution is compared to the content the user has added to the overlay.

Outline and landmark have three difficulty settings; easy, medium and compete. The difficulty "easy" shows both an image of the task and its solution. "Medium"

does not show the solution until the user has confirmed an answer. The "compete" difficulty only shows the task without a solution, but the user has limited time. The goal here is to solve as many tasks as possible over a fairly short time-period.
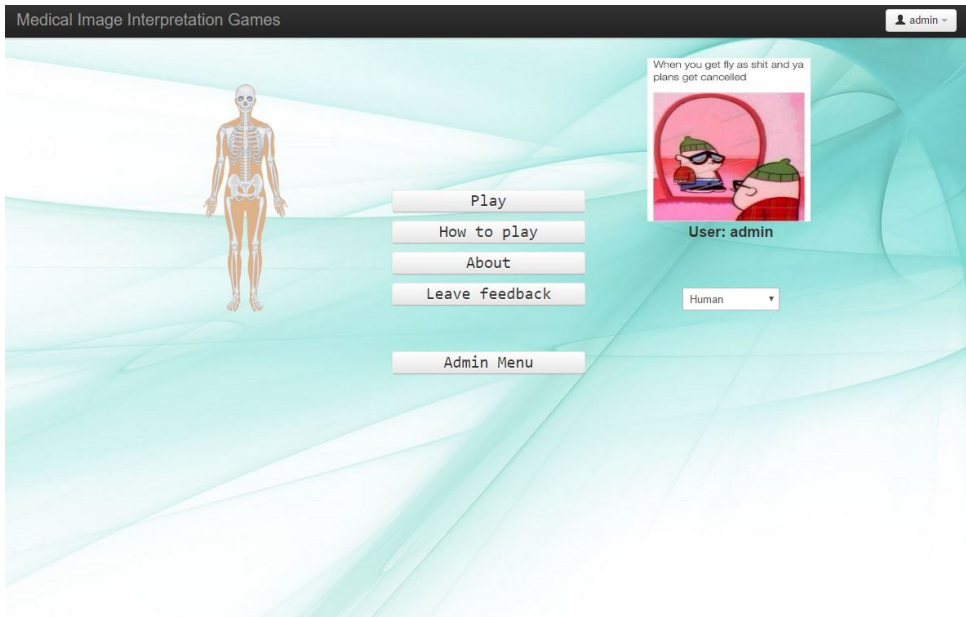
(a) The main menu window
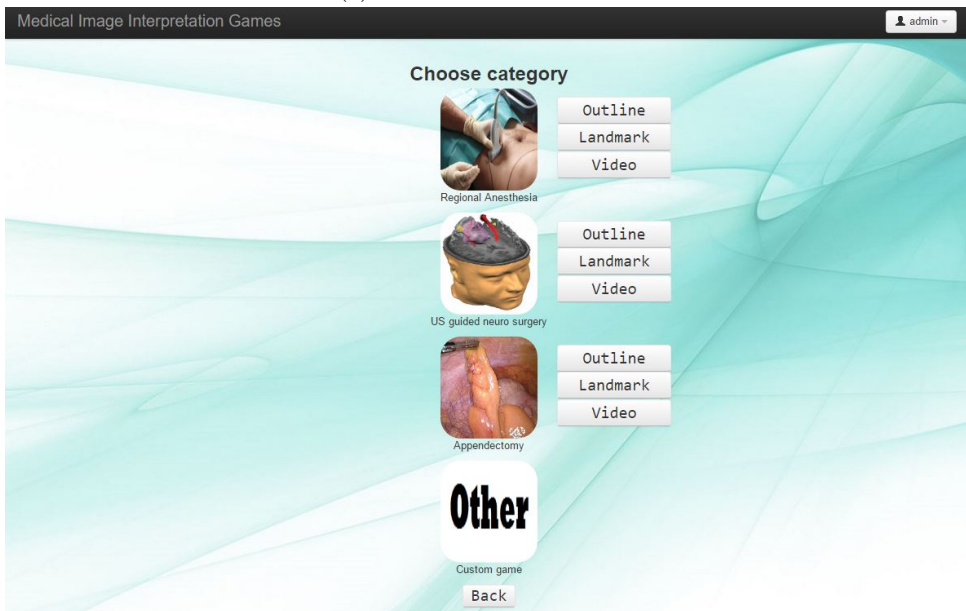
(b) The category options window
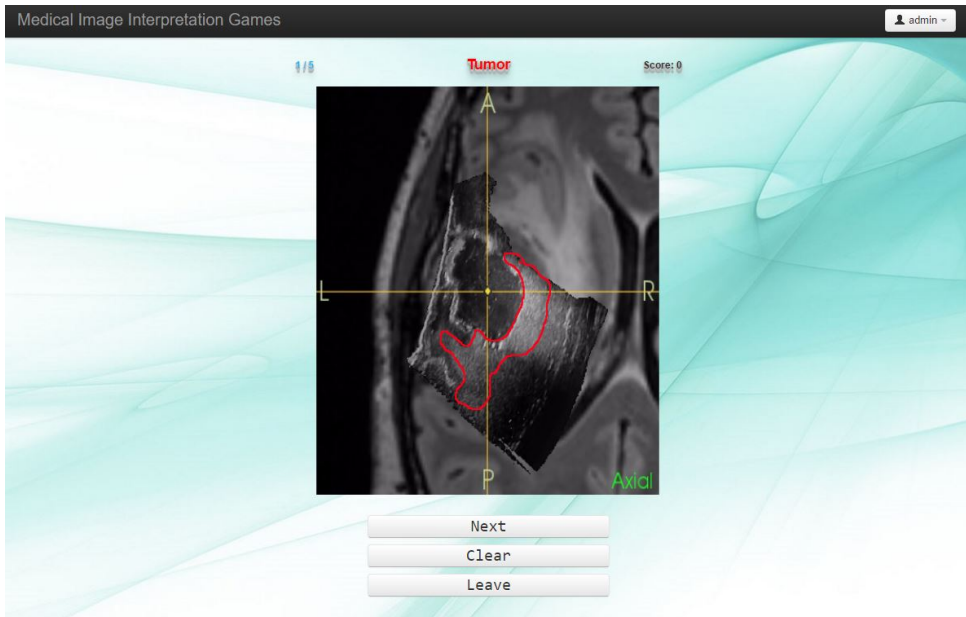
(c) The compete mode window

(d) The game mode window

Figure 4.1: Screen-shots of the application on a desktop computer

4.2.1   Outline

The game mode "Outline" provides the users with the possibility to outline structures in an image. This is a way of teaching the users shapes and locations of different structures in any image. The player is first presented with the different difficulty settings. When a difficulty is chosen, they are presented with an image and task-text. The task text tells the player what structure to outline and the player will receive a score based on how exact the player was.

Scoring

Comparing two images can be done in many ways. The first implementation was very simple and only compared the pixels of the solution to the user-input. When most of the functionality of the site was completed, this system was updated.

The updated scoring system uses the distance between the pixels to calculate a score. For each pixel in the solution, the closest pixel from the user-input is located and the distance between them is calculated. The mean distance between all these points is used to create a score. To optimise the algorithm without much accuracy loss, some pixels are skipped. A visualisation of this scoring system is shown in figure 4.2.
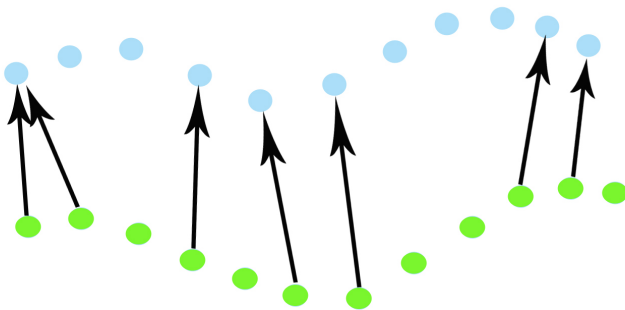
Figure 4.2: Visualization of the scoring in the game mode landmark, green indicating the solution and blue the user-input

Max score is achieved if the mean distance is below a certain threshold. If the mean distance is outside this threshold, the score is calculated based on the mean

distance.

4.2.2   Landmark

The game mode "Landmark" is similar to the game mode "Outline" in the sense that the players are presented with an image and a task-text. The player is asked to point and click where they think a certain structure is in the image instead of outlining it.

Scoring

The solution can have any shape, but is usually a line or a closed/semi-closed loop.

The implemented scoring system has three phases:

– Check if the point is inside the solution on the x-axis

– Check if the point is inside the solution on the y-axis

– Check if the point is on or very close to the solution line.

The system accounts for semi-closed loops, but, as shown in the figure 4.3, the point has to have at least three reference points.

a)   b)   c)

Figure 4.3: Example of the implemented scoring of landmarking. a) and b) are valid, c) is not valid.

A full score is achieved if the point is inside the solution or on the solution line. Half score is achieved if the point is very close to the solution line.

4.2.3   Video

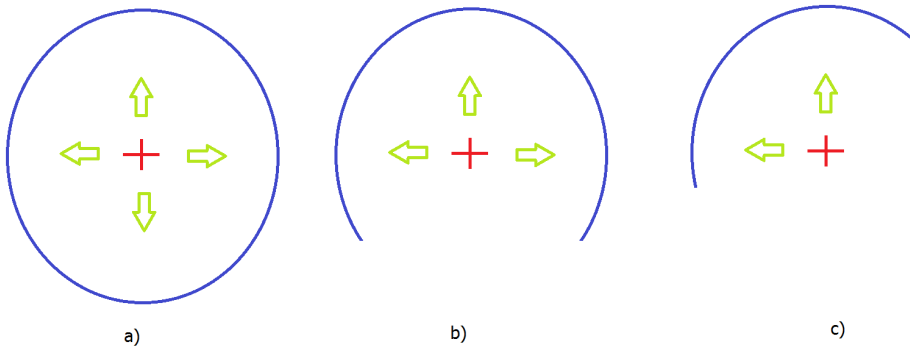The game mode "Video" focuses on the scanning skills of the users. Such skills are needed in many areas within medicine, for example when an ultrasound technician attempts to find a good view to perform the procedure femoral nerve block. This game mode can also be used just to view a video of an actual procedure, and then ask the user what was done wrong or could have been done better.

Each video-task has three potential stages:

– Find a good position in the video for the task at hand.

– Outline or landmark a certain structure in the video. The player will be moved to a specific position in the video.

– Multiple choice questions

Which stages each task has is set when creating the solution.

Scoring

Scoring of the three stages is simply correct or incorrect, except for the outline and landmark, which uses the methods mentioned for the respective parts.

4.3   Scoreboard

Both the game mode outline and landmark has a "compete" difficulty. The scores from this difficulty are stored in a database and shown in the game mode screen with data stored for the given category and game mode. As shown in the figure 4.1d, the scoreboard contains the username, affiliation and score for that particular category and game mode.

4.4   Administration interface

The administration interface, as shown in the figure 4.4, gives certain users access to both upload and manage content. Only users with access level 20 can use the "user administration"-interface.
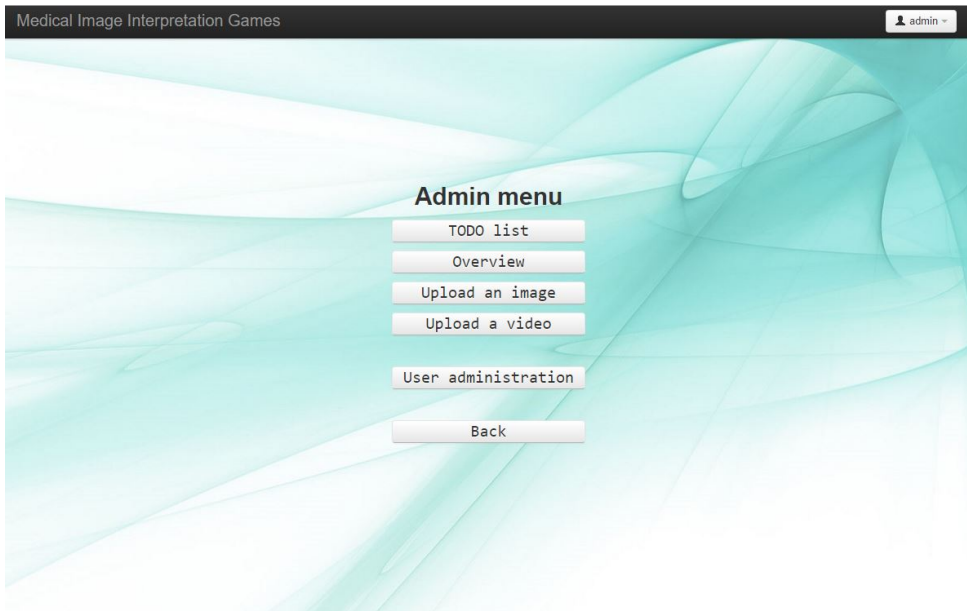
Figure 4.4: Category overview of the game type US guided neuro surgery

4.4.1 TODO list

The "TODO list" is a feature that allows experts to view all the content that has been assigned to them for solution creation. This eases the process of finding content that the experts can create solutions for. The feature is only visible to the users that have a unsolved tasks assigned to them.

4.4.2 Content overview

The category overview is a tool for the administrators to keep track of the content active in the different categories. First the user has to choose the desired species, category and image type, and based on these options a list of all the videos and images are presented. The list contains information about each item, as shown in figure 4.5, and administrator has the option to view, edit or delete the specific any item at any time.

Figure 4.5: Category overview of the game type US guided neuro surgery

4.4.3   Solution creation

To be able to have up-to-date content, a system for adding and modifying content is necessary. An uploader can either, create a solution or assign an user to do it. If the uploader assigns someone else, the task will be marked with "no-solution", and it will be shown in the assigned user's "TODO list".

4.4.4   Images

The expert or administrator is first presented with the dialogue shown in figure 4.6c where they choose the correct specie, clinical application and image type for the image.. The figure 4.6a shows the screen where they can open an image and either create a solution or upload it without a solution. They also have the option of assigning the image to a specific user.

4.4.5   Videos

The administrators are presented with the same dialogue as for image uploading. The figure 4.6b shows the screen for uploading videos. They can also be assigned to a specific user in the same way as for images.
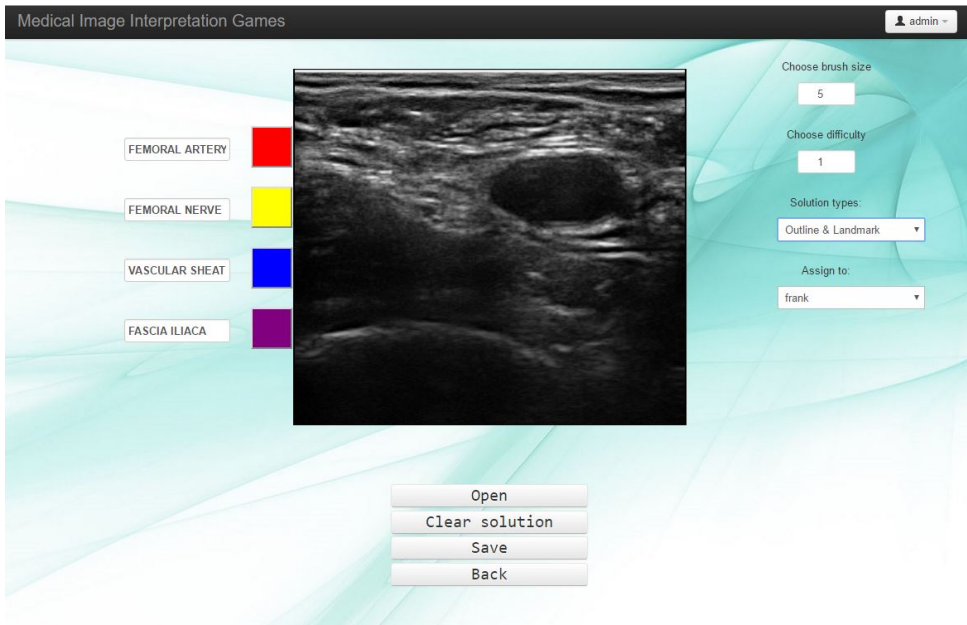
(a) Image upload screen with example image
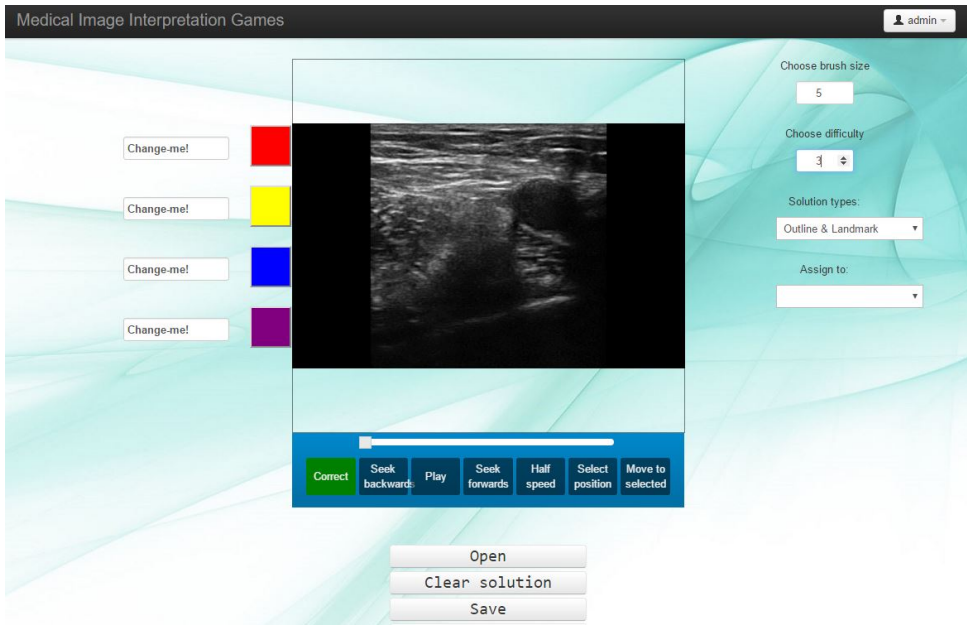
(b) Video upload screen with example video
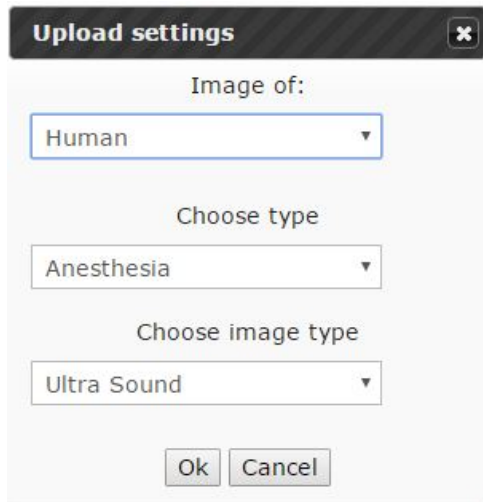
(c) Upload settings dialogue.

Figure 4.6: Image and video upload design

4.4.6   User administration

The access level of new accounts are set to 0, which is enough to play the game, but nothing else. Experts and content up-loaders need an access level of 10 to be able to upload and edit content. With the user administration, it is easy to manage the users and give certain users higher access leves. The interface is only available for users with access level 20.

4.5   Database configuration

The database configuration is not very complicated. The only relations is between the "User"-table and the "Scoreboard"-table shown in figure 4.7a, where the username and the affiliation of the user are the foreign keys. The other two tables only contain information about the task and the type of task it relates to.

(a) The tables "Users" and "Screborad" in the database

(b) The tables "Images" and "Videos" in the database
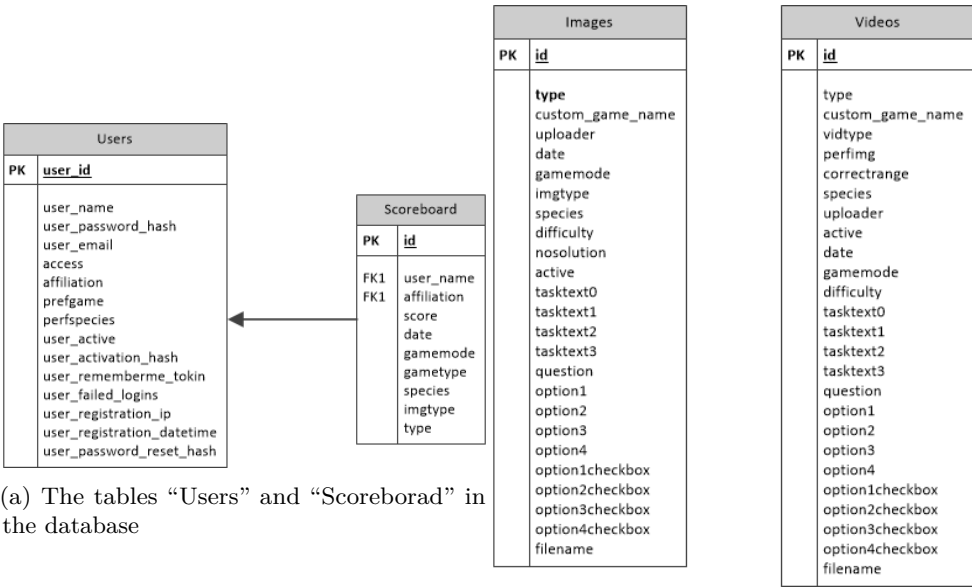
Figure 4.7: The database configuration of MIIG

4.5.1   The application on a mobile device
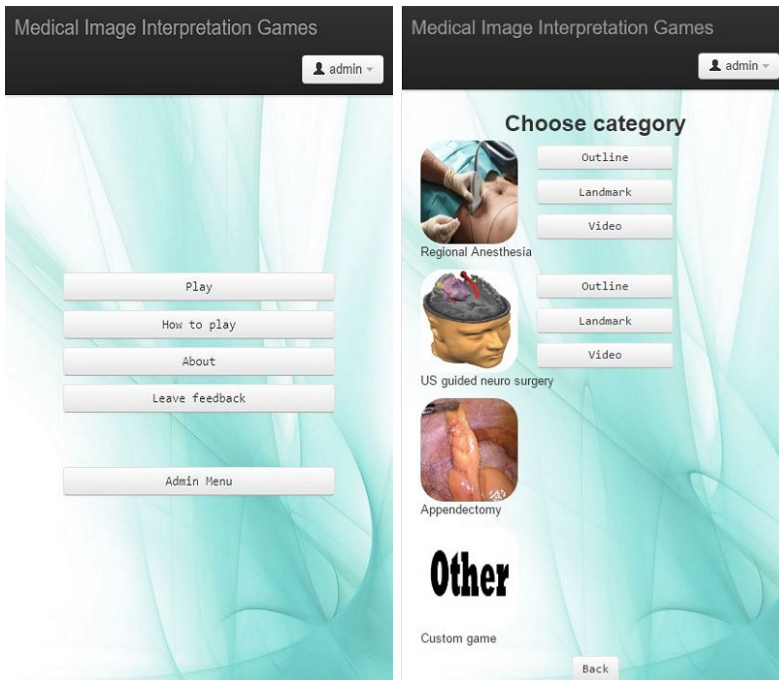
(a) The main menu window   (b) The category options window
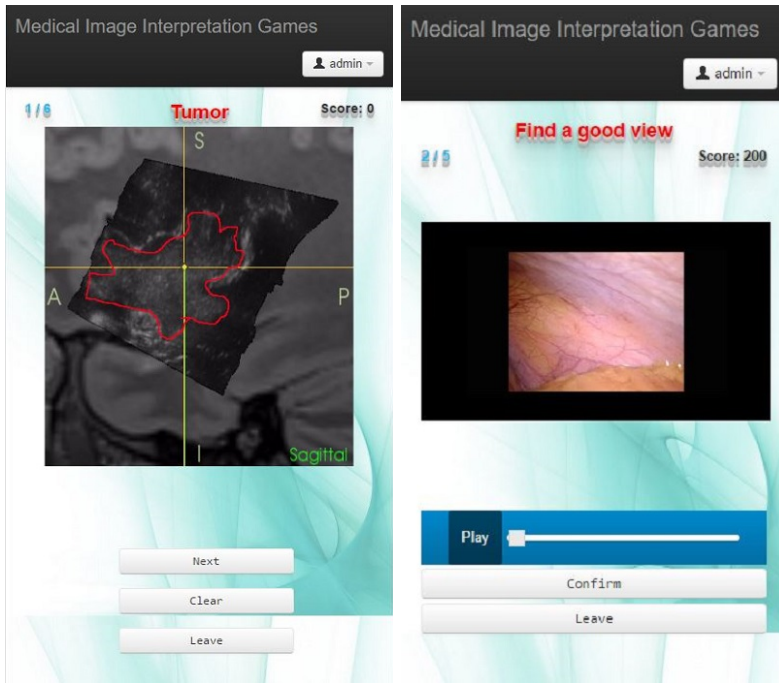
(c) The game window   (d) The game mode video
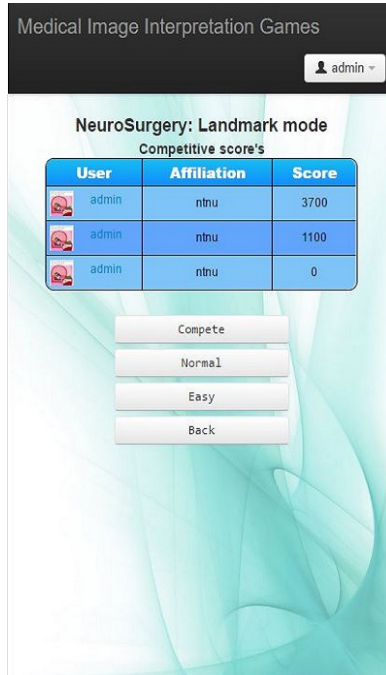
(e) The game mode window

Figure 4.8: Screen-shots of the application on a mobile device

4.6   Fulfilment of Functional Requirements

FR 1   Three different game modes. The three game modes are available in all categories, given that the there are content available.

FR 2   The game modes should have the difficulty-options easy, normal and competitive. Only the game modes "Outline" and "Landmark" has these difficulty options.

FR 3   In the video game mode, the player should locate a correct spot for the given task. The game mode "Video" is divided into two parts, stop in a good position and "Outline/landmark" a certain thing in the image.

FR 4   There should be an option for adding textual questions to images.
The textual questions are only the "task-text", meaning the goal of the task in each game mode.

FR 5   It should be possible to upload new content.
FR 5 is fulfilled by an interface for uploading both videos and images. The uploader can choose to either make a solution or assign another user to annotate the image.

FR 6   There should be an admin-interface for administrators.
The application has implemented an admin-interface that is only accessible for users with a certain access-level. The interface has options for managing content, uploading new content and user-administration. If a user has been assigned content to make annotations on, they will have a "TODO list" where they can easily locate this content.

FR 7   There should be a private game mode where users may upload content.
The FR 7 is fulfilled in the sense that users with access level 10 or higher can create private games. Any user can access the game, given that they have the game-code.

FR 8   The application should have a scoring system with high-scores.
The application has a scoreboard in all clinical applications, but only for the game mode "Outline" and "Landmark". The game mode "Video" does not contain a competitive difficulty, and therefore does not have a scoreboard.

FR 9   Each user should have their own profile.
The FR 9 is fulfilled by the profiles created when a user is created. The user can modify their own profile, and view other user's profiles.

4.7   Development time-line

The schedule mentioned in section 3.4 was a good reference point for the development. The figure 4.9 shows the actual time-line of the project.

ID	Task	Start	Finish	Duration
1	Initial planning	11-01-16	22-01-16	10d
2	Initial meeting – defining project goal	25-01-16	25-01-16	2h
3	Requirement planning	22-01-16	29-01-16	6d
4	Initial development – login and gameplay design	18-01-16	02-02-16	12d
5	Meeting – functionality and design	03-02-16	03-02-16	2h
6	Development – design and functionality improvements	03-02-16	14-03-16	29d
7	Meeting – Hands-on testing of appendix removal practice tool	09-02-16	09-02-16	3h
8	Meeting – admin-interface discussion	16-03-16	16-03-16	1h
9	Development – admin-interface, solution creation and upload functionality	16-03-16	18-04-16	24d
10	Meeting – discussed what remains before we can start alpha testing	19-04-16	19-04-16	2h
11	Development – minor changes to prepare for alphatesting	19-04-16	26-05-16	28d
12	Development – documentation	02-05-16	13-05-16	10d
13	Meeting – Timeline for alphatest – design changes	04-05-16	04-05-16	2h
14	Alpha-testing active	16-05-16	03-06-16	15d
15	Meeting – Final fixes before alpha-testing	25-05-16	25-05-16	1h
16	Development – modifications based on feedback from test-phase	30-05-16	10-06-16	9d 4h

Figure 4.9: Actual project progress

5

Results

This chapter will present the results of this thesis. Section 5.1 presents the expected way to use the application both as a player and an administrator, and section 5.2 presents the results from the user-testing. The last section, 5.3, presents the changes made based on the user-tests.

5.1   Using the application

In this section, the way to use the application is described using sequence diagrams and images . The application usage is divided into two parts; playing and managing/uploading content.

5.1.1   Playing

Anyone, even users without an account, can play the game. An example of the sequence of a player using the system is shown in the figure 5.1.
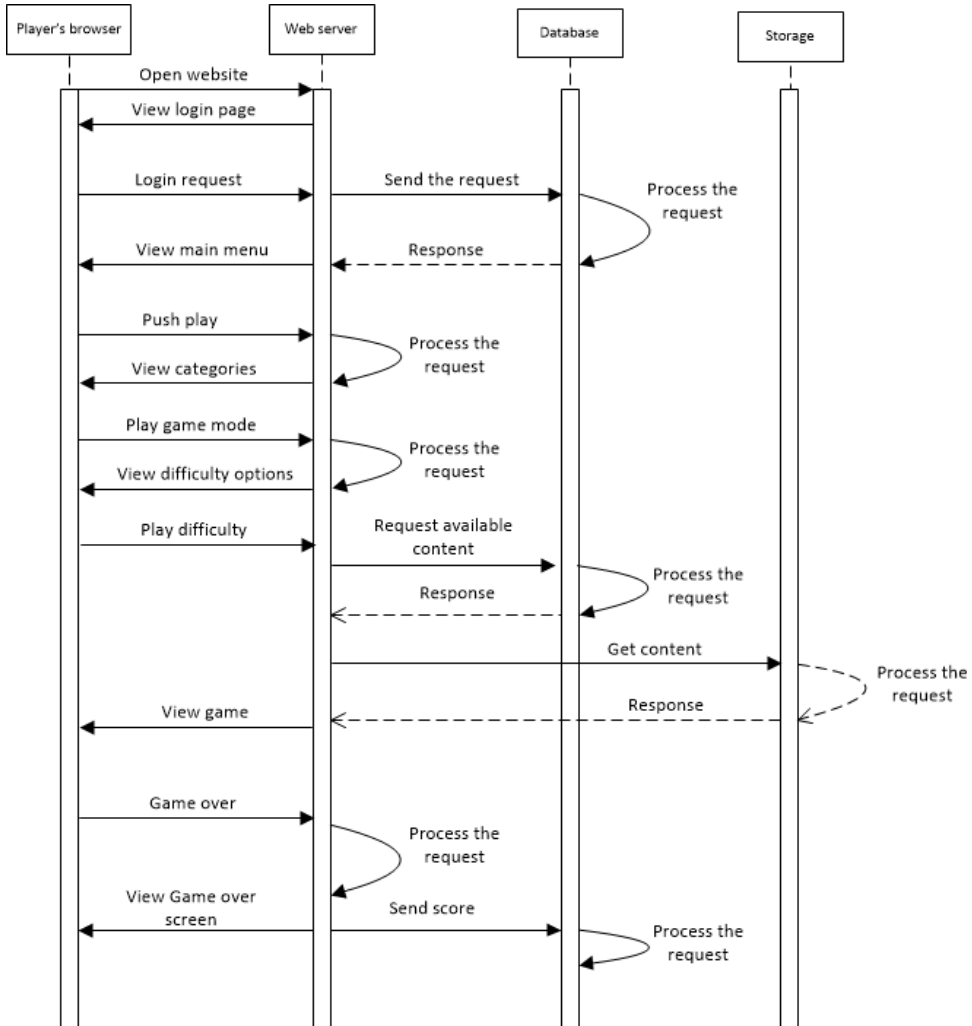
Figure 5.1: Sequence diagram of the player

(a) View login

(b) View main menu

(c) View categories

(d) Choose difficulty

(e) View game

(f) View game over screen
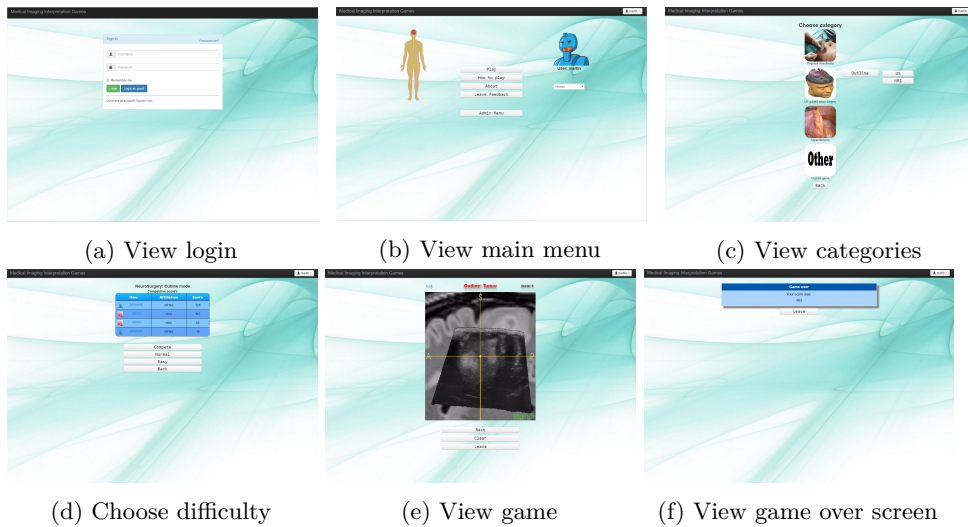
Figure 5.2: Playing the game sequence in pictures

The figure 5.2 shows the same as the sequence diagram, but with images. A player opens the website and login to the main menu. When the user clicks "play", all the categories with available content are shown. The user selects a category and game mode and is moved to the difficulty options screen. When a difficulty has been chosen the game screen is shown where the user can play the given mode. If the difficulty is "compete" the scores will be saved and shown in the scoreboard, in the other difficulties the score will just be shown to the user.

5.1.2   Managing and uploading content

The main difference between the administrators and the experts, is that the administrators can modify the access level of the users. In figure 5.3, the administrator represents both experts and administrators. An example of the sequence of an administrator using the system is shown in the figure 5.3.
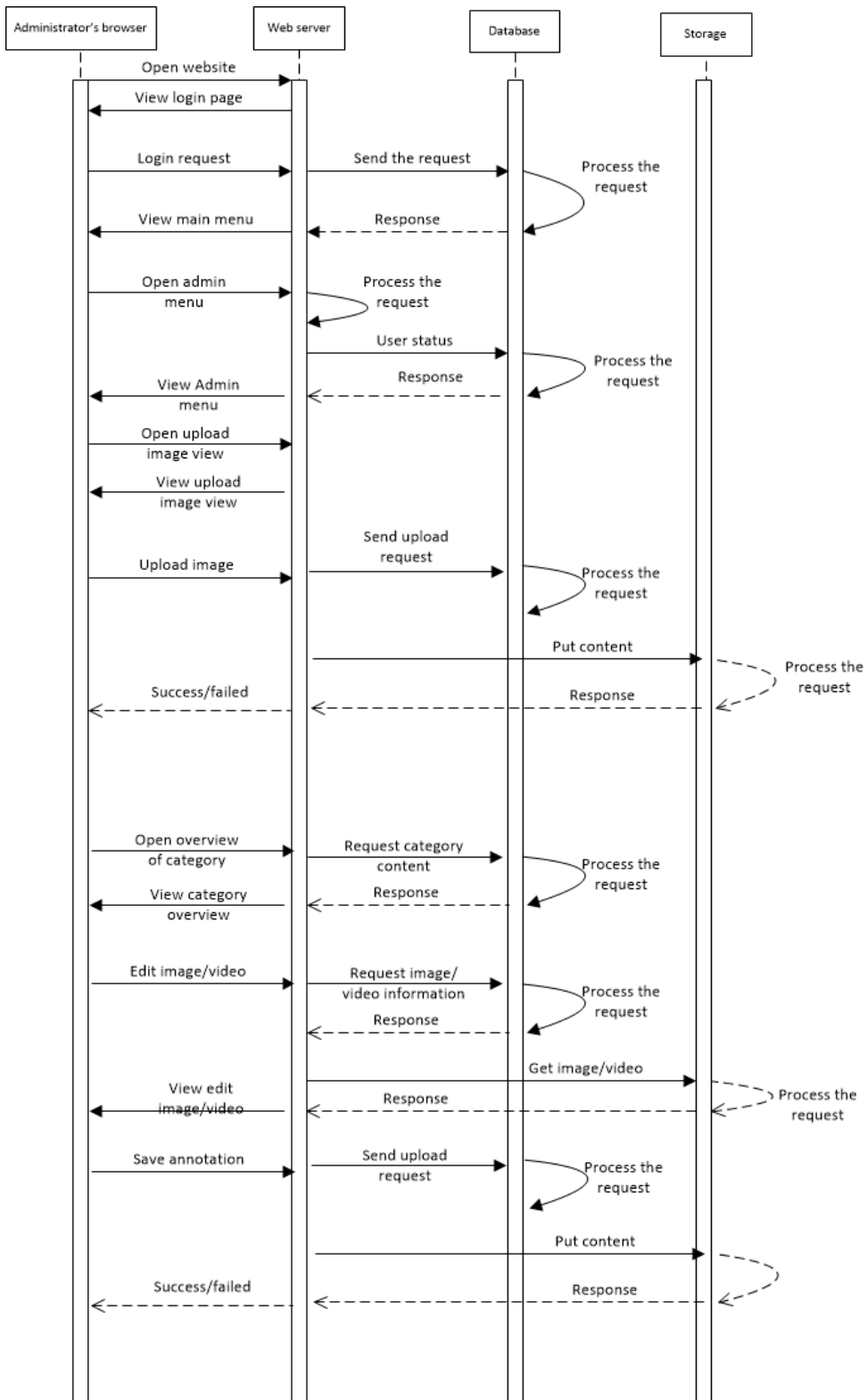
Figure 5.3: Sequence diagram of an administrator

(a) View login

(b) View main menu

(c) View admin menu

(d) View upload image

(e) Upload image

(f) View overview of category

(g) Edit solution

(h) Save solution
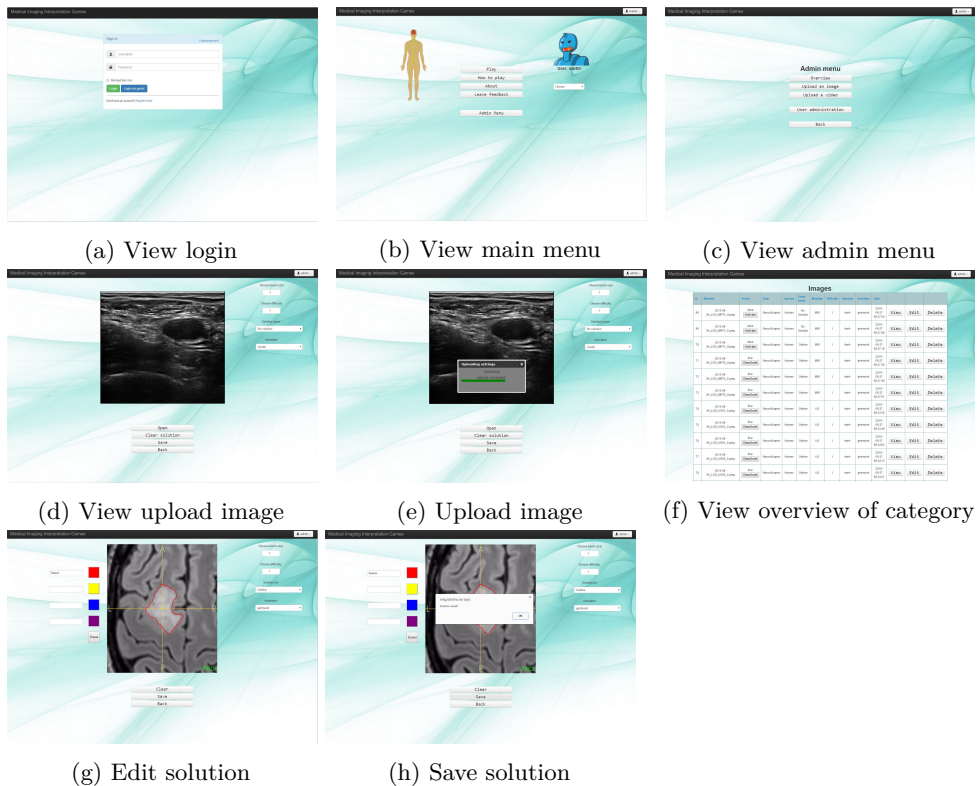
Figure 5.4: Managing and uploading content sequence in images

The figure 5.4 shows the same as the sequence diagram, but with images. After the user has logged in, the "admin menu"-button can be accessed given that the user has a certain access level. In the admin menu the user can choose to upload an image or video. They then get to a screen where they open a image they would like to upload. They can, if they have the necessary skills, create a solution or assign another user to annotate the image before uploading. An overview of all the images in the different categories can be viewed by pressing the "Overview"-button. Only the uploader and the assigned user can create solutions for a given image. The administrator can, when an acceptable solution has been created, activate the image to make it available in the game.

5.2   Evaluation

In this section, the feedback received through the modified SUS will be evaluated. Due to limited time and challenges concerning gathering material for the application, only small scale testing was possible and some of the test results came in just a few days before this thesis was due. Two tests was conducted, one with clinician and technologist experts and one with a random selection of testers.

The margin of error is quite high when there are few participants in a test. It is recommended to have 20 participants in a test when collecting quantitative usability metrics[24]. With 20 participants the margin of error is +/- 19%, compared to with 10 participants where the margin of error is +/- 27%. Unfortunately, there are not many experts that are available to participate in the tests, which increases the margin of error.

The first test was with a random selection of users and was conducted with guidance over Skype. They were both asked to test the standard game categories as well as a custom game designed for the particular participants. The group consisted of 6 users with different backgrounds and educations. This test was mainly to bug-test the application and get feedback on the design from users with a lot of computer experience. All the participants filled out SUS forms.

The second test consisted of 6 participants, from both St Olav's Hospital and SINTEF/NTNU. The technologists were asked to test both the game and the upload features, while the clinicians were asked to test the game and the solution creation system. Having professionals evaluate the application and comment on whether or not they think the application can be a good tool to teach image interpretation, and if they think the content management system was good is crucial for the applications future. All the participants filled out the SUS forms.

A planned large scale test will be carried out at the 8th international course of "Ultrasound in Neurosurgery". The National Advisory Unit for Ultrasound and Image-guided Therapy organises the course, and it is arranged on June 14 - 15, 2016. The results from this test will be interesting to see and evaluate, and it is unfortunate that it will not be a part the evaluation in this thesis.

5.2.1   Results from the test at SINTEF

The experts were informed about what and how to test the system over email, and were asked to do it within a few days. There were no reports of problems during this test, and the results are shown in the table 5.1.

Table 5.1: Application SUS Scores from the SINTEF test

#	Question	Avg	Score
1	I think that I would like to use this system frequently	3	2.0
2	I found the system unnecessarily complex	1.8	3.2
3	I thought the system was easy to use	4.4	3.4
4	I think that I would need the support of a technical person to be able to use this system	1.4	3.6
5	I found the various functions in this system were well integrated	4.2	3.2
6	I thought there was too much inconsistency in this system	1.8	3.2
7	I would imagine that most people would learn to use this system very quickly	4.2	3.2
8	I found the system very cumbersome to use	1.2	3.8
9	I felt very confident using the system	4	3.0
10	I needed to learn a lot of things before I could get going with this system	1.4	3.6
11	The information on this system is credible	3.75	2.75
12	This system is too slow	1.4	3.6
		SUS score	**80.18**

Using the Adjective Rating scale mentioned earlier, see figure 2.6, the score translates to "Good". The most noticeable score is from question 1 where few of the testers answered that they think they will use the system frequently. It is difficult to analyse the reason for this, but it may be because their skills are proficient enough and they do this sort of procedures regularly enough to not need a system to practice. A SUS score of 80 is quite high, and is a good indication that this application could, with some improvements and further development, be a useful tool to teach different image modalities.

Textual feedback

The users had an option of leaving textual feedback. A summary of the constructive feedback is listed below.

– Show the solution for a longer period of time in normal mode

– The scoreboard and the difficulty-settings could swap position

– The difficulty "Easy" should be reworked, it currently has no learning effect

  - Maybe through a button to show the solution instead of showing it from the beginning

– A stack of images where the user can scroll through may be better than random 2D images in a non-standardized plane.

– There should be an option for uploading multiple images

– When creating a solution it should be possible to erase parts of the solution

– An eraser should be available when creating solutions

Below is a summary of the comments users made about what they liked about the application and its potential.

– Good user-interface

– The framework behind the system is very well thought through

– Easy to use

– The application has a great potential in becoming a useful tool for training in image interpretation

  - It can be extended to a lot of different training applications

5.2.2 Results from the random selection

There were no problems during the test and the users did not need much guidance to use the system. They filled out the form as well as verbal feedback during the test. The results are shown in the table 5.2.

Table 5.2: Application SUS Scores from the random selection test

#	Question	Avg	Score
1	I think that I would like to use this system frequently	4.43	3.43
2	I found the system unnecessarily complex	1.57	3.43
3	I thought the system was easy to use	4.71	3.71
4	I think that I would need the support of a technical person to be able to use this system	1.00	4.00
5	I found the various functions in this system were well integrated	4.14	3.14
6	I thought there was too much inconsistency in this system	1.57	3.43
7	I would imagine that most people would learn to use this system very quickly	4.29	3.29
8	I found the system very cumbersome to use	1.43	3.57
9	I felt very confident using the system	4.71	3.71
10	I needed to learn a lot of things before I could get going with this system	1.57	3.43
11	The information on this system is credible	3.86	2.86
12	This system is too slow	1.00	4.00
		SUS score	**87.36**

Using the Adjective Rating scale mentioned earlier, see figure 2.6, the score translates to "Excellent". The goal with this test group was to find bugs and get feedback on design. The users are not the target audience, therefore this score will not get too much weight, but a SUS score of 87 indicates that the users liked the system and its functionality.

5.3   Application improvements

The textual feedback form gave the users the option to give more detailed feedback on the system and its features. The following changes and features were implemented into the system based on this feedback.

- An eraser when uploading images
- Uploading multiple files

– Solutions are shown for a greater period of time in the difficulty-mode "Normal"

It is expected that the large scale test during the 8th course of "Ultrasound in Neurosurgery" will produce more feedback that can be used to improve the application further.

Chapter 6

Conclusion

The motivation behind this thesis is developing a serious game which can be used as a tool to teach image interpretation of different image modalities. The game is based on two theses that were completed in the spring of 2015 and 2014.

One of the theses developed a serious game which promotes the student's ability to interpret ultrasound images of the femoral nerve which is necessary in order to perform the procedure called nerve block, the other for locating tumour borders in images of the brain. Both theses teach the users to interpret images, which applies to may procedures within medicine, but the applications were separate and difficult to expand to cover other types of procedures. Two projects was carried out in the spring of 2015 evaluated the two theses, and suggested that the best way forth was to develop a new web-based application which incorporates both games.

The name of the web application developed, Medical Imaging Interpretation Games (MIIG), is defined in a way that it is not restricted to a specific procedure or image modality. MIIG allows anyone to play and practice the different categories that are available. Each category try to invoke the competitiveness between the players by having a scoreboard with user-names and the user's affiliation. The application also has an administrator interface where images and videos can be uploaded. Experts in the different fields can create solutions that later can be made available in the game. MIIG was developed with a goal of being a game that can cover many areas, and it is easy to expand the application to cover even more areas than the ones currently available.

The web application was evaluated and the results are presented in this thesis. The result showed that the web application was useful, easy to use, educational and challenging. However, the application was only evaluated by a few neurosurgeons and technologists, which may not give the same results as an evaluation done by the main audience (students).

Chapter 7
Future work

For this application to be a success and an useful tool for students more user-testing is needed. The application may require some redesign. The development was done over a relatively short period, and some requirements came very late in the development, leading to undocumented and "messy" code.

The application is generalised in the sense that it has three game modes that can have pictures of anything, which makes this application applicable to other areas such as learning how to analyse dental x-rays. It may even apply to other areas outside medicine.

7.1 Expanding the area of use

As mentioned, this type of application may be useful in other areas within medicine. Areas where the application may be used to teach image interpretation:

– Anatomy

   Locate organs

   Locate different bones and knuckles

   Locate nerves

   Diagnose eye deceases

      - Spotting signs of pathology

– Dental

   Locating holes

   Locating teeth that should be removed (Wisdom teeth)

   Other teeth problems seen in x-ray or with normal pictures

- – Microscope images

      blood smears

        - Analyse images to see if there are traces of cancer or other illnesses.

      Skin biopsy

A lot of the syllabus in medicine, some mentioned above, requires memorising, and could be easier to memorise through a game.

The application is not limited to pictures of humans. For example, veterinary educations require much of the same type of content to be memorised. And pictures are great tools for this.

According to the veterinary Hege Hjelkrem [25], a veterinary at "Sørum og Fet Veterinærkontor", as a student she spent a lot of time using microscopes to identify different illnesses etc. She says that this was time-consuming and that a tool for viewing such images could be a useful for veterinary students.

- – Animal anatomy

      Locate organs

        - locate deformed organs

      Locate different bones and knuckles

      Locate nerves

      Diagnose eye deceases (see fig. 7.1d)

   - Spotting signs of pathology

- – Microscope images

   Locate abnormalities in blood(cancer cells etc.)(see fig. 7.1e)

      Histological (see fig. 7.1a)

   - Sectioning of tumours and other tissue/biopsy

The application is ready to cover other topics, but as mentioned, the category interface may need to be redesigned. The biggest challenge with adding new categories is that it requires content and experts to create solutions.
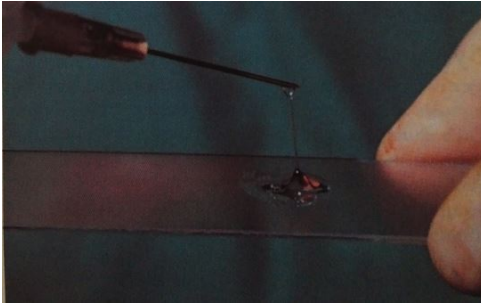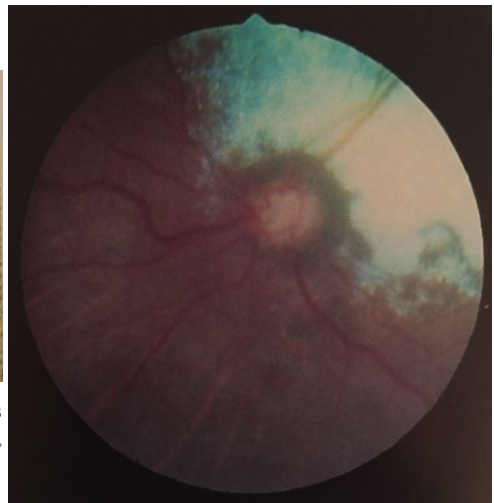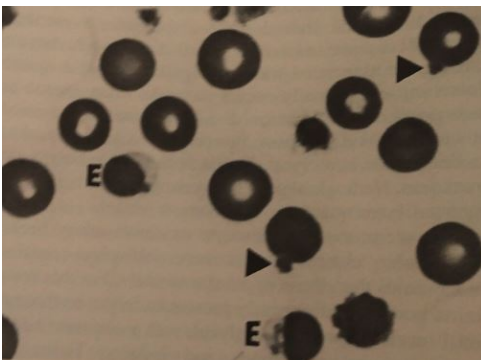
(a) Glass microscope slide with sample
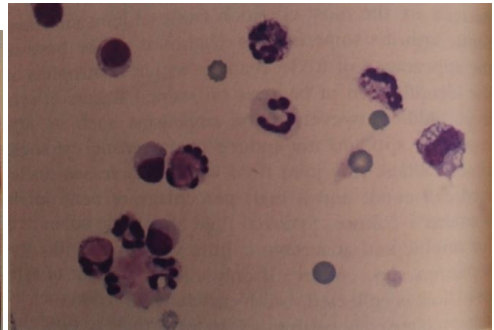
(b) Synovial fluid from a German Shepard with polyarthritis
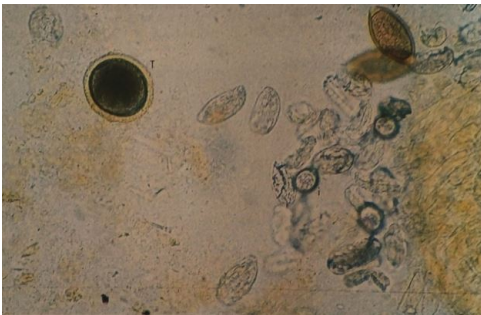
(c) Photomicrograph of fecal flotation analysis from dog, demonstrating characteristic ova from whipworms

(d) Retina of a dog with chronic glaucoma

(e) Blood smear; dog. Eccentrocytes (E) and erythrocytes containing Heinz bodies (arrowheads) in a dog with hemolytic anemia from the ingestion of onions.

Figure 7.1: Example of areas that may be used in the application. Pictures from: [26], [27] and [28]

7.2   Redesigning the category interface

If many categories are added to the application, it would be necessary to redesign it to make it more user-friendly. This can be done in may ways, and are somewhat dependent on the number of categories and their relations.

The interface could be changed to allow the user to search for appropriate categories as well as the ability to browse.

7.3   Optimizations

The application was developed with the main intention to get a working application. Therefore, there may be some duplicate code and poor variable naming. Even though some time has been spent on removing these flaws, some may remain.

In this section, some of the features that could use an upgrade are mentioned.

7.3.1   Automatic solution creation

There are many ways to extract anatomical structures from an image. Most methods require seed points based on some criteria, which makes the methods semi-automatic. They can contribute to making a suggested solution. Some of the most common ways are:

– Region growing

– Thresholding

– Active contours

– Watershed

By implementing one or more of these methods, one can simplify the process of making solutions or even make them almost entirely automatic.

7.3.2   Mobile optimization

As mentioned in section 3.2, the application is divided into a desktop and a mobile device version. The only real difference is that they use different style-sheets(CSS). The application might run better on mobile devices if the two were separate. The mobile device users would be redirected to the mobile version, while the desktop users are redirected to the desktop version. It is also mentionable that the design for mobile devices could be renewed.

7.3.3   CSS clean-up

When creating a web-application some of the styles may be duplicated under different names because one uses different naming for each part of the application. By going through the ".css" files and removing such duplicates and unused code one may experience an increase in performance of the application and the codes readability.

7.4   Better beginner mode

The game mode "easy" is not very helpful in the sense that the solution is fully visible. A better way of helping the players along may be to only show part of the solution, depending on how well they are doing.

7.5   Adaptive difficulties

A game mode where the user can choose the difficulty, and based on the chosen difficulty the game can become harder and harder if the user manages to solve the tasks. If the user fails to solve the tasks the difficulty would become easier, making the user learn at the appropriate level.

7.6   Zoom

When accuracy is a factor, it is often a wanted feature to be able to zoom. This feature should be implemented, at least so that the experts can create the best possible solutions.

7.7   Backup

To avoid situations where content disappears, either through user error or malicious users, a backup solution should be implemented.

7.8   Uploading of multiple files

This feature was implemented very late and only works on images. This feature should be tested thoroughly and expanded to also work for videos.

7.9   The scoring system

The application needs to be tested and used to be able to evaluate the scoring system and to make adjustments to make it as fair as possible.

7.10   The known issues and bugs

– If the browser is resized page must be reloaded to work properly.

– Video game mode solution is not always accurate.

– Landscape mode on mobile devices does not work.

7.11   The most pressing changes

Based on feedback from the clinicians and technologists, some new features and changes would make the application better. Uploading multiple files, zoom and a better beginner mode was mentioned and should be prioritized. Further more the game mode "Video" should be thoroughly tested to make sure solutions are accurate.

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