NTNU – Trondheim
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Teaching Ultrasound-Guided Regional Anesthesia Through Mobile Phone Games

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Abstract

It is now quite common to use ultrasound as guidance when regional anesthesia is performed in hospitals around the world. However, to be able to use ultrasound during procedures, an anesthesiologist needs experience in ultrasound interpretation. If ultrasound data routinely collected from medical procedures are made available through an educational mobile application, there is potential for students of anesthesia to acquire knowledge through independent study.

To study the potential behind the idea, a mobile application prototype, *Nerve Blocker*, was created and evaluated based on educational value and people's willingness to use it. The evaluation was performed through user testing.

The evaluation showed that by making *Nerve Blocker* a fun game centered around ultrasound interpretation, the participants showed willingness to use the application. The evaluation also indicated that the participants had improved at ultrasound interpretation through exposure in the application.

If *Nerve Blocker* is expanded to include more areas of regional anesthesia, and additional data per area, it could become a promising teaching tool to be used to supplement formal education.

Sammendrag

Det er blitt mer og mer vanlig å bruke ultralyd som guide når regional anestesi blir utføres på sykehus rundt om i verden. For å dra full nytte av ultralyd trenger en anestesilege erfaring i tolkning av ultralydbilder. Hvis data som rutinemessig blir samlet inn fra prosedyrer kan bli tilgjengeliggjort gjennom en mobilapplikasjon, har dette potensial til å gi anestesistudenter muligheten til å tilegne seg kunnskap gjennom selvstudium.

For å undersøke potensialet bak denne ideen ble en applikasjonsprototyp, *Nerve Blocker*, utviklet og evaluert basert på pedagogisk verdi og folks vilje til å bruke den. Evalueringen ble utført via brukertester.

Evalueringen viste at ved å gjøre *Nerve Blocker* til et morsomt spill basert på ultralydtolkning viste deltagerene villighet til å bruke den. Evalueringen indikerte også at deltagernes ultralydtolkning var blitt forbedret via eksponering i appen.

Hvis *Nerve Blocker* blir utvidet til å inkludere flere områder innenfor regional anestesi, og ytterligere datamateriale per område, vil den kunne bli et lovende læringsverktøy som kan supplere formell utdanning.

Preface

This thesis is the result of the work completed for our Master of Science and Technology degrees in Computer Science at the Norwegian University of Science and Technology. The work was carried out during the spring semester of 2015, in collaboration with SINTEF and St. Olav's Hospital.

We would like to thank our supervisor Frank Lindseth for his help and guidance during this project. We would also like to thank Kaj Johansen for providing medical data and feedback. Next, we would like to give our gratitude to the employees at SINTEF who participated in the user test. Finally, we wish to thank Johan Helsing for his help and constructive feedback.

Hanna Holler Kamperud & Solveig Hellan
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Glossary

FNB femoral nerve block.

GUI graphical user interface.

IDE integrated development environment.

Imaging modalities The technologies and techniques used to aquire diagnostic images of the body. Examples of imaging modalities include X-ray, ultrasound and MRI.

LGPL Lesser General Public License.

MRI magnetic resonance imaging.

MVC model-view-controller.

NTNU Norwegian University of Science and Technology.

RA regional anesthesia.

SDK software development kit.

SUS system usability scale.

WWDR Intermediate Certificate Apple's World Wide Developer Relations (WWDR) certificate. It is used to certify builds by linking the development certificate to Apple.

X-ray radiography.

Chapter 1

Introduction

In the practice of medicine, anesthesia is essential to perform medical procedures painlessly. General anesthesia is a medically induced coma that affects the entire body. It requires a great deal of preparations, and is not risk free. In cases where only anesthetization of a specific body part is required, *regional anesthesia* is often preferred.

Ultrasound technology is rapidly becoming more common in procedures called *nerve blocks*, an area of regional anesthesia. By using ultrasound, the anesthesiologist can guide a needle inside the patient's body with the help of real-time images. The procedure is cheap, effective and safe for the patient.

It is important that anesthesiologists have proficient skills in ultrasound interpretation to successfully perform the procedures. However, since ultrasound images are inherently noisy, they are often regarded as more difficult to interpret than other medical imaging modalities, such as CT and MRI [15]. Lack of knowledge about ultrasound interpretation is one of the main challenges when investing in this technology. Consequently, when training new professionals in ultrasound interpretation, it is very beneficial to expose students to many different ultrasound images of all the areas they wish to become proficient in.

1.1 Problem definition

The national competence center for ultrasound and image guided therapy is a collaboration between three institutions in Trondheim, Norway: SINTEF, Norwegian University of Science and Technology (NTNU) and St Olav's Hospital. The center works to improve current surgical methods, and to develop new

techniques for minimally invasive surgery, with a special focus on ultrasound-guidance [10]. Within the center, unique ultrasound data is collected weekly.

The objective of this thesis is to use the collected ultrasound data to help teach relevant groups to interpret ultrasound images. A prototype of a mobile game application that incorporates the data, will be made. The application's area of focus will be on the *femoral nerve block*, a specific regional anesthesia procedure that provides anesthesia for the anterior thigh, the knee, and the femur. The ultrasound data used will therefore be femoral ultrasound images. The application, named Nerve Blocker, should teach the material in an entertaining manner, encouraging users to learn.

The main target group of the application is students and physicians training to become anesthesiologists. The application has potential to be used in combination with traditional teaching methods. The application may also be relevant to anesthesiologists who want to refresh their knowledge and other groups wishing to learn ultrasound interpretation.

1.2 Thesis goals

The main goal of the project is to create an application prototype that can teach femoral ultrasound interpretation in an entertaining manner. As further development of the application is desirable, a prototype will be developed with maintainability and scalability in mind. It should be made easily available to as many people as possible, and the application size should be manageble. Finally, the prototype should be tested by an appropriate audience. The test should examine the application's usability, educational value and its ability to motivate users to learn.

1.3 Research questions

In addition to the goals mentioned above, the thesis will answer the following research questions:

RQ1 Is the application able to effectively teach ultrasound-guided regional anesthesia using routinely collected data?

RQ2 Is the application able to motivate medical professionals to actually use it?

1.4 Thesis outline

The thesis consists of eight chapters.

Chapter 2 Background presents the research done prior to implementation.

Chapter 3 Method states the methods used to develop the application and evaluate it based on the research questions

Chapter 4 Implementation describes how the application was implemented and evaluated.

Chapter 5 Results presents the results from the evaluation.

Chapter 6 Discussion discusses the results from the evaluation in relation to the research questions.

Chapter 7 Future work presents possibilities for future development.

Chapter 8 Conclusion gives a conclusion of the project

Bibliography contains the references used

Appendix A SUS survey

Appendix B usefulness questionnaire

Appendix C results from usefulness test

Appendix D an article about the project published in Gemini - Science news from NTNU and SINTEF

Chapter 2

Background

To develop an educational application with medical content some background knowledge is required. This chapter presents these topics and techniques.

In section 2.1, regional anesthesia is explained with focus on the femoral nerve block technique. Afterwards, in section 2.2, some theory on the making of an educational game is presented. Section 2.3 is an introduction to application development for mobile phones, while section 2.4 details the programming framework Qt and different elements of prototype development. Lastly, in section 2.5, an overview of the existing solutions on the topic is given.

2.1 Ultrasound-guided regional anesthesia

In this section, the basics of ultrasound technology are explained as well as their use in regional anesthesia. Finally, the femoral nerve block procedure is introduced, along with how it is usually taught in teaching institutions.

2.1.1 Ultrasound technology

Ultrasound imaging is an imaging modality often used in diagnostic medicine. Other modalities frequently used include magnetic resonance imaging (MRI) and radiography (X-ray), though many other medical imaging techniques exist.

Ultrasound technology is based on high frequency sound waves which the human ear can not register. An ultrasound probe emits sound waves that penetrate and resonate in soft tissues. Since anatomical structures have different

Figure 2.1: Two examples of ultrasound devices. The one on the left is a typical ultrasound device, the one on the right is a hand-held version
Source: [14, 6]

abilities to bounce an echo, they may be represented in an ultrasound image by assigning grayscale colors to the different echoed waves. By registering the strength of the sound wave compared to the amount of time it took to echo back to the ultrasound probe, the depth and grayscale value of a point may be determined. Dark areas in an ultrasound image represent anatomical structures with a high water content, i.e. blood vessels. The high water content allows the waves to transmit "easily with little reflection" [13, p. 664], which in turn is represented with a dark color.

There are several advantages to using ultrasound technology in medicine.

- It is relatively cheap compared to other imaging modalities, like MRI and X-ray.
- Ultrasound devices are portable, and often have wheels. Hand-held devices have also become more and more common in recent years, see figure 2.1.
- Images are created in real time, often at 30 frames per second, depending on the quality of the device.

- There are no observed side effects of ultrasound imaging, and the technology is considered very safe to use. [13, p. 657]

In spite of its many advantages, ultrasound is not always a suitable imaging modality for medical use. Ultrasound devices produce comparatively low resolution images that show little detail. Taking advantage of ultrasound images also requires an experienced interpreter, which may contribute to initial difficulties in using the technology.

2.1.2 Regional anesthesia

The Columbia University Medical Center defines regional anesthesia (RA) as "a form of anesthesia in which only a part of the body is anesthetized" [1]. When the term RA is used, it is generally to indicate that a relatively large part of the body is anesthetized, i.e. the hand, the lower leg, or an entire arm.

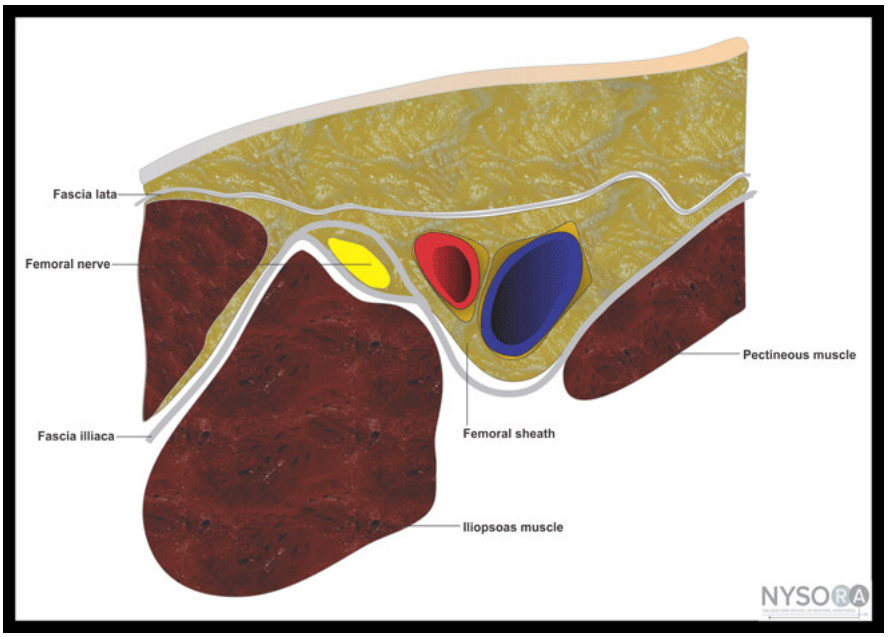


Figure 2.2: A cross-section of the upper thigh illustrating the anatomy of, and around, the femoral nerve
Source: [28]

When performing RA on a limb, it is common to use a procedure called *peripheral nerve block*. An example of a peripheral nerve block is the femoral nerve block (FNB). The FNB anesthetizes the entire leg of the patient, and is

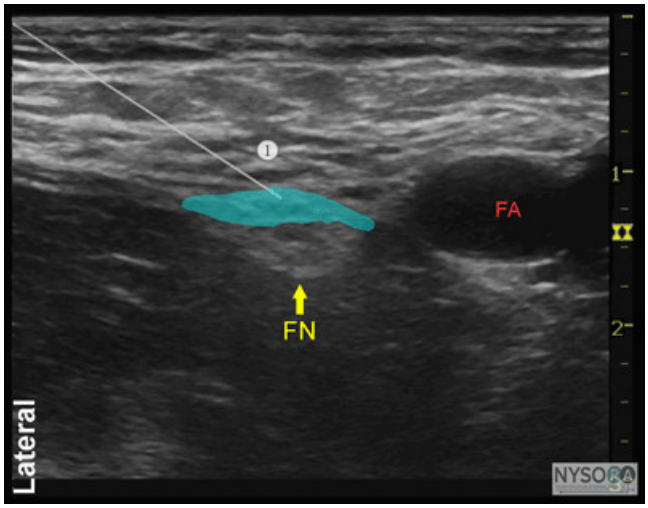


Figure 2.3: Needle placement in femoral nerve block
Source: [29]

performed on the upper thigh. To perform the block an ultrasound probe is positioned to display important anatomical structures illustrated in figure 2.2. A needle is positioned between the femoral nerve and the fascia iliaca as seen in figure 2.3. An anesthetic is injected into the area surrounding the nerve, consequently numbing it.

To help position the needle correctly a few techniques may be used. In recent years, the use of ultrasound-guided nerve blocks have gained popularity due to their advantages of "improving patient safety and interventional anesthesia efficacy" [32]. The ultrasound transducer acquires real-time images of the needle insertion, which is the reason ultrasound is chosen over any other imaging modality. [13, p. 657]

2.1.3 Teaching ultrasound-guided femoral nerve block

In his book *Textbook of Regional Anesthesia and Acute Pain Management*, Hadzic describes the process of learning how to perform ultrasound-Guided Regional Anesthesia as follows:

> 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 recognize nerves). Scanning practice and review of teaching files are critical. [13, p. 660]

The term *scanning skills* entails the process of positioning the ultrasound transducer correctly, to display the correct anatomical structures. It is important for the operator to have full control over the position of the anatomical structures before continuing with the procedure.

2.2 Game development

The term *gamification* may be defined as the "process of game-thinking and game mechanics to engage users and solve problems" [39]. Creating a game from educational content may be described as gamifying the content.

In his article "What makes things fun to learn? Heuristic for designing instructional computer games" [25], Thomas W. Malone points out three different characteristics he thinks are essential to make a computer game enjoyable: challenge, fantasy, and curiosity. These three characteristics - explained below - will be considered when designing the game concept.

2.2.1 Challenge

Thomas W. Malone says that "In order for a computer game to be challenging, it must provide a goal whose attainment is uncertain." His article suggests the following ideas in order to provide an appropriate goal:

- Simple games should provide an obvious and compelling goal. Goals may be made obvious and compelling by the use of visual effects or fantasy.
- Users should be able to easily generate goals of appropriate difficulty.
- The best goals are practical or fantasy goals.
- The players must be able to tell whether they are getting closer to the goal or not.

It is also important that the outcome of the game is uncertain, i.e. whether the player will win or loose. Malone suggests four ways to make the outcome of a game uncertain.

- Variable difficulty level: Automatically based on level of player, chosen by player, or determined by an opponent's skill.
- Multiple level goals: Several different levels of goals. Basic goal, subgoals, metagoal.

- Score-keeping: Metagoal to get as high a score as possible.
- Speeded responses: Metagoal to do something as fast as possible.
- Hidden information: Guessing games, provoke curiosity.
- Randomness: Gambling games, may heighten interest.

Lastly, on the subject of challenge, the article states that goals and challenges in games engage the player's self-esteem. Therefore the game should have a variable difficulty level and appropriate performance feedback to make sure the player's self esteem is not lowered.

2.2.2 Fantasy

Concerning the fantasy aspect, Malone says that "In general, games that include fantasy show or evoke images of physical objects or social situations not actually present." Furthermore, the fantasy aspect is divided into intrinsic and extrinsic fantasies. An extrinsic fantasy depends on the skill, but not vice versa, such as in the game Hangman. With intrinsic fantasy the skill in the game is also dependent on the fantasy. An example would be a game of darts where the player calculates the physics behind the arrow in order for it to hit the target.

2.2.3 Curiosity

Finally Malone states that "Curiosity is the motivation to learn, independent of any goal-seeking or fantasy-fulfillment." Malone distinguishes between *sensory* curiosity and *cognitive* curiosity.

Sensory curiosity may be evoked through changes in physical factors such as audio and visual effects. The effects are meant to attract the attention of the learner. In computer games these effects may be used as decoration, to enhance fantasy, as reward or as representation system (i.e. "Represent and convey information more effectively than with words or numbers.")

Cognitive curiosity, on the other hand, occurs when the learner has a desire to modify existing cognitive structures. This may be achieved by presenting the learner with just enough information to make their existing knowledge seem incomplete, which in turn will motivate them to learn more and thus improve their cognitive structure.

2.3 Mobile application development

When developing games for the mobile phone market it is important to consider what operating system to develop for. In figure 2.4, the market share of each smartphone operating system is graphed. Google's Android dominates the market with a market share of 78.0 % in the first quarter of 2015, while Apple's iOS comes second with 18.3 %. Together Android and iOS have a market share of 96.3 %, which is why applications are predominantly developed for these two operating systems, see figure 2.5. The rest of the market shares are divided between Windows Phone, Blackberry OS, among others.

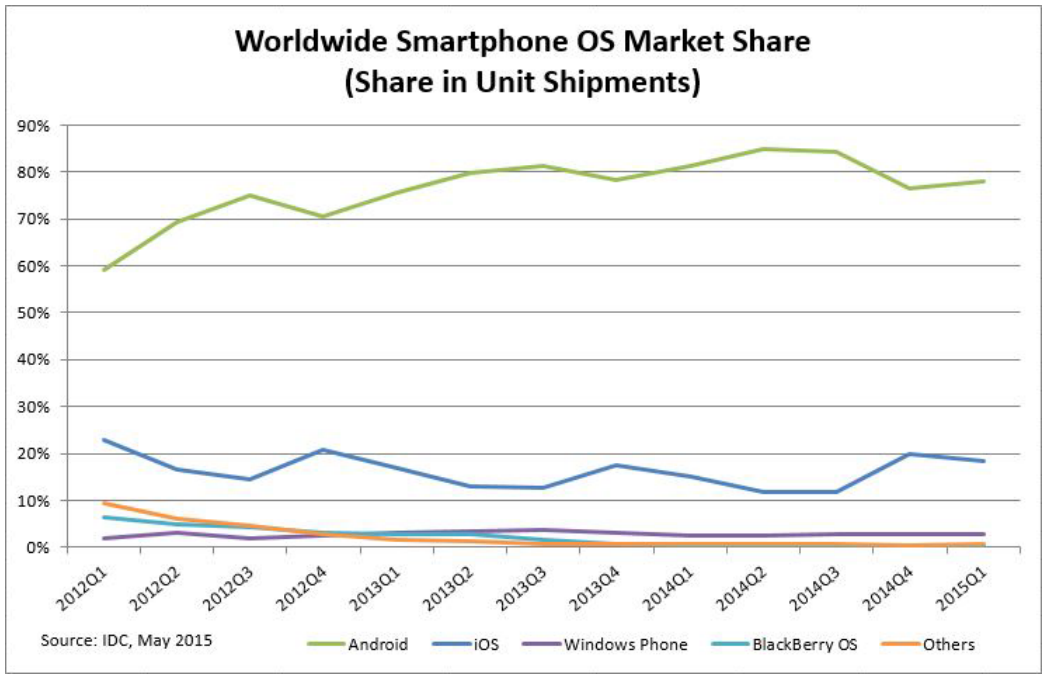


Figure 2.4: The market share of each smartphone operating system
Source: [2]

2.3.1 iOS development

To develop iOS applications, a Mac computer running the latest version of OS X is needed, as well as the latest version of Xcode. Xcode is an integrated development environment (IDE) developed by Apple. The iOS software development kit (SDK) is included with Xcode and extends Xcode to include the tools, compilers, and frameworks necessary for iOS development. As long as the iOS SDK

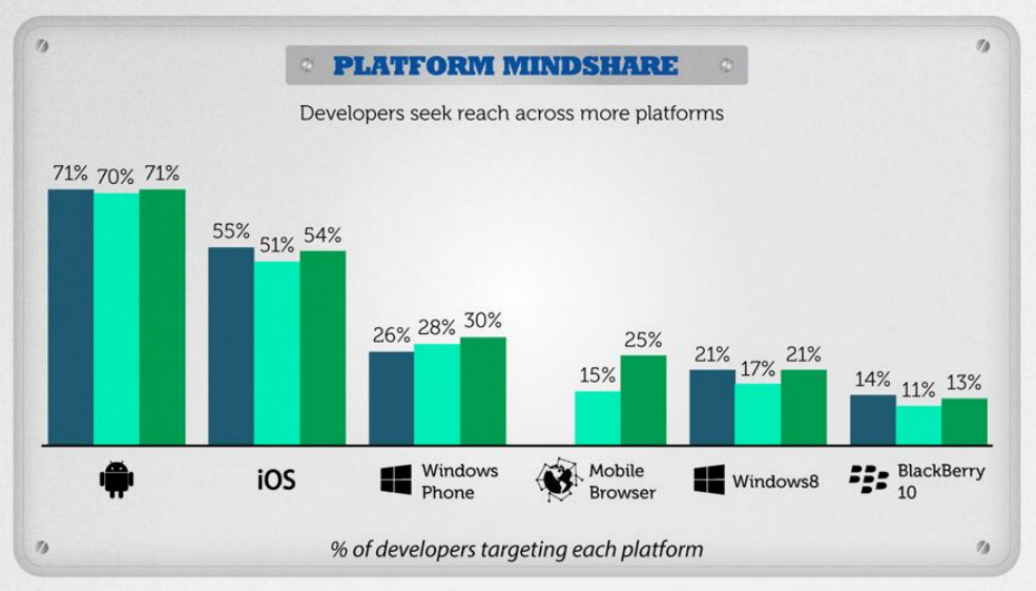


Figure 2.5: An overview of which platforms developers are currently targeting
Source: [38]

is installed, other IDEs may be used for development. The iOS simulator is included in Xcode, and may be used run the application. It can simulate different models of both iPads and iPhones, with different screen sizes. [19]

Deploying an application to a device

To install the application on a device for testing, it is necessary to register with Apple's developer program and pay an annual subscription fee. Once the registration has been approved by Apple, the deployment process may be started by logging into the Apple Developer Member Center [16]. From there a development certificate may be generated, downloaded and installed in the Mac's keychain. In addition the WWDR Intermediate Certificate needs to be downloaded and installed in the keychain.

Once the certificates have been installed, the device(s) to be used for testing must be registered in the Apple Developer Member Center. Currently, devices are identified by their UDID (Unique Device ID), which may be obtained through Xcode or iTunes.

Then an App ID needs to be created. This is a unique identifier for the application and it may be created in the Apple Developer Member Center. Finally a provisioning profile file may be created. The provisioning profile gathers the certificates, the list of permitted devices, and the App ID. The generated pro-

visioning profile file must be downloaded and installed on the development computer. The application may now be deployed on the device. [3]

Publishing to the App Store

The App Store is Apple's application marketplace.

The signature in the provisioning profile makes it possible to submit the application for App Store approval. After the application is uploaded to iTunes Connect, Apple will review the application. This may take up to two weeks. If the application is approved, the status in iTunes Connect changes to "Ready for Sale". If it is rejected the status changes to "Rejected" and feedback on issues that caused the rejection is given. [20]

There are several reasons why the application might get rejected. Some common reasons include crashes, bugs, substandard user interface, and broken links. [18]

The developers decide what it should cost to download the application from App Store, and receive a 70 % share. The application may also be released for free. [17]

2.3.2 Android development

When developing applications for the Android operating system there is substantial freedom to choose which platform to work from. Windows, OS X and Linux are all supported. Although many frameworks and IDEs may be used to develop Android applications, they all depend on the Android SDK which may be downloaded from the official Android website [22]. Once the SDK is installed, many programming languages may be used for development, including Java, C# and JavaScript.

A common way to test an application, is to run it in an Android emulator, e.g. Genymotion. Code may also be deployed straight to an Android device. To install unofficial applications on Android the target device has to allow installations from unknown sources. To deploy directly to the device it also has to be in developer mode, a setting that opens up debugging options on the device .

Publishing an application

There are several ways to publish an Android application, though the most common approach is to use an application marketplace, like Google Play. Other approaches include independent distribution through e-mail or a website. How-

ever, every device that wishes to install an independently published application must allow installations from unknown sources as described earlier.

In order to publish to Google Play there are a few additional steps to consider. First, the application must be built to get an apk-file. Then the application must be signed digitally by creating a keystore with a certificate. The application does not need to be registered with a certificate authority. More information can be found here: [23].

To upload the signed apk a Google Play Developer Account is necessary, which may be obtained by paying a one time $25 fee. The apk is then uploaded to Google Play's servers along with a description and at least two screenshots of the application being used.

2.3.3 Cross-platform development

Cross-platform development is becoming more and more popular. VisionMobileTM said in a report published February 2015 that "The percentage of developers using cross-platform tools has grown from 23 % to 30 % over the last 6 months". [38]

The advantages of using cross-platform development tools is the ability to write code only once, instead of writing separate code for every operating system. This has the potential to cut development time significantly, reaching a larger amount of users on the same development budget.

There are several cross-platform tools to choose from and many considerations to take into account when choosing one.

- Cost of use
- Licensing
- Target platforms supported
- Development platforms supported
- Developer support provided
- Ease of use
- Performance of resulting application

Some popular cross-platform tools include PhoneGap, Xamarin, Sencha, Unity, Qt and Marmalade.

2.4 Qt

Qt is a cross-platform development tool currently owned by the Finnish company Digia. It is developed by the subsidiary Qt Company in what is called the Qt Project [8]. Qt is developed under open source governance, allowing other firms and individuals to expand Qt as well.

2.4.1 Qt basics

With the release of Qt 5 in December of 2012, Qt Quick and the new markup language, QML, were made available to improve Qt user interface development. QML is a high-level, scripted and declarative language commonly used for developing mobile applications where touch input and user friendliness are important. QML also allows more flexibility by using JavaScript to implement simple logic. [30]

When starting a Qt Quick application, a JavaScript runtime is created which QML runs under. The runtime runs with a Qt-based back-end. The back-end is traditionally written in C++, although other languages are available (i.e. Java).

QML may use C++ in two ways. C++ classes may be registered as new types that QML imports. These types are treated as any ordinary QML type. The other way is to register an existing C++ instance into the runtime context of QML. Subsequently, the object is may be accessed in the QML. When the instance is changed a signal is fired that lets all subscribing parties know that a change has occured. QML is a subscriber to these signals and subsequently knows when to update the user interface to display the new information. This mechanism of signals and subscribing slots is an advantage of using Qt as it automates some necessary features.

As mentioned earlier, Qt is a cross-platform application framework. This means that Qt code may be written once and then be compiled for several different platforms. Consequently, the development time is shorter, since Qt takes care of adapting the source code to fit the target platform. Since Qt compiles independently for different, platforms it is compiled into native code for each platform.[1] An example of this native compilation of Qt is the fact that QML code creating a *MenuBar* will create a different looking menu bar on different platforms even when compiled from the same line of code, see figure 2.6

[1] This does not apply to QML code, which is not compiled natively.

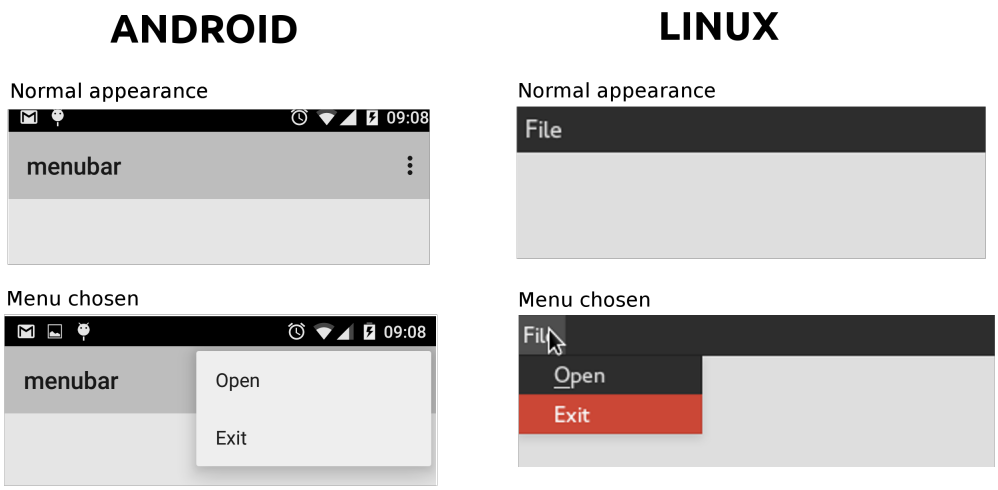


Figure 2.6: A menu bar created from the same QML code compiled onto two different platforms, Android and Linux

2.4.2 Qt Creator

Qt Creator is an IDE created by the Qt Project, se figure 2.7 . It includes a visual debugger and an integrated graphical user interface (GUI) designer. The IDE automatically detects compilers existing in the system and uses them to compile and debug code. It is available for Windows, Linux and OSX may build code for several targets including iOS, Android, Windows Phone, BlackBerry, embedded Linux devices as well as the desktop operating systems Windows, Linux and OS X. [9]

While Qt Creator keeps track of all project files in an easily accessible manner it also has integration with version control systems, such as Git and Subversion. The integrated GUI designer displays a preview of the application being developed, see figure 2.8. It allows the developer to set properties for QML elements without having to compile and run the code, receiving feedback immediately.

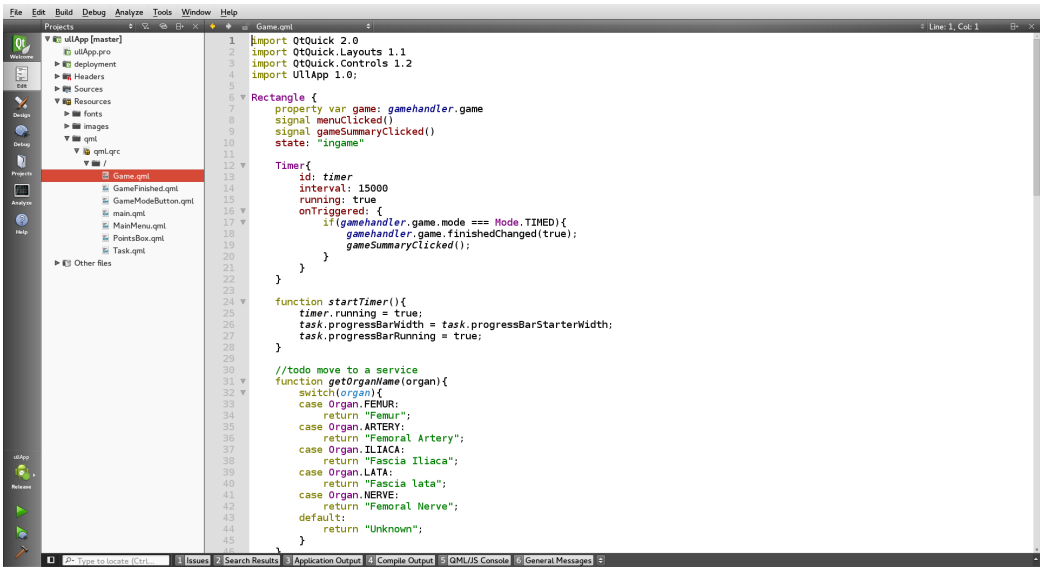


Figure 2.7: Qt Creator in edit mode

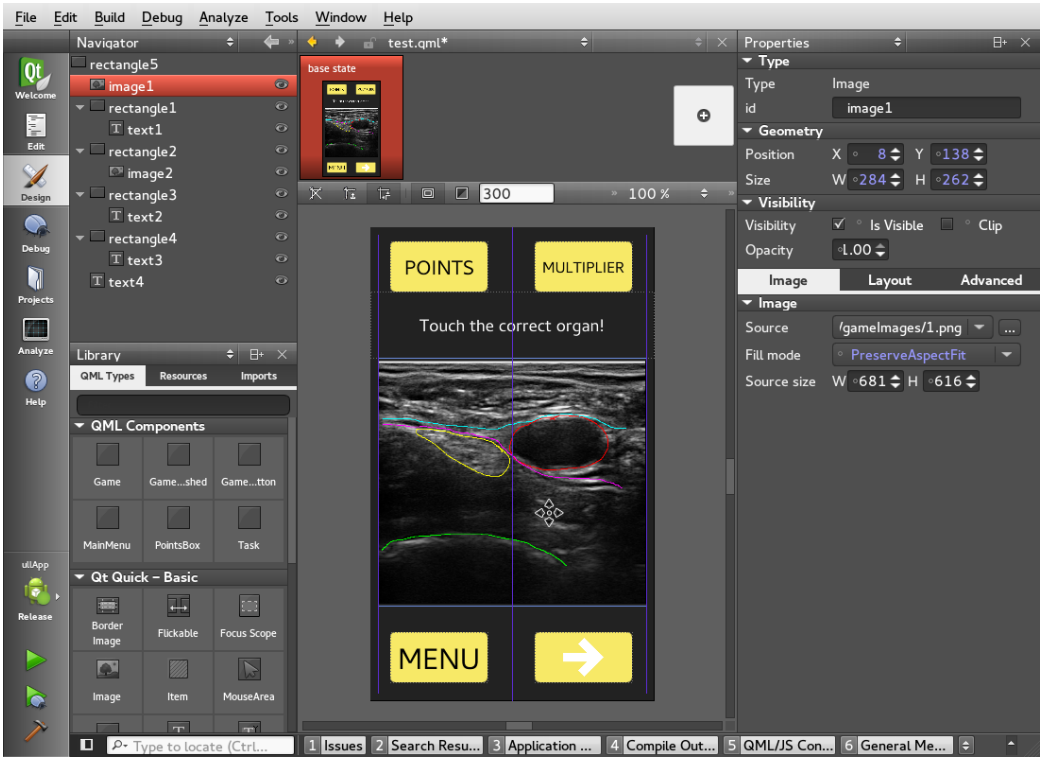


Figure 2.8: Qt Creator in design mode

2.4.3 Publishing Qt applications

Qt is available with commercial and open source licenses. The Lesser General Public License (LGPL) allows commercial distribution of closed source code within certain limitations. This license is an advantages of using Qt, since partially closed source applications may be distributed without paying large licensing fees.

To publish an application with LGPLv3 there are certain obligations that need to be fulfilled [31]. To start with, the complete source code of Qt needs to be provided for the user. If the Qt framework has not been edited for the application, it is sufficient to provide written instructions on how users may download Qt themselves. Secondly, the source code may be kept private as long as it may be considered "work that uses" the Qt library. This means that the application should only link to the Qt library dynamically, and not statically. Dynamic linking is default in Qt. Thirdly, the user has to be able to run the application with a modified version of the Qt library, and "it is your obligation to provide the user with all necessary tools to enable this process" [31]. The publisher is also "obliged to provide full instructions on how to install the modified library on the target device" [31]. Lastly, a copy of the LGPLv3 has to be provided to the end-user to notify them that LGPL licensed software is being used .

2.5 Existing solutions

A survey of games and applications that are similar to this project was conducted. The survey resulted in the following findings where all the applications are educational and focused on ultrasound-based navigational technology.

2.5.1 Ultrasound-guided needle placement game

The thesis *A Serious Game for Learning Ultrasound-Guided Needle Placement Skills* [5] describes the development and evaluation of a game targeted towards future intervention radiologists. The game aims to help train the skills of needle placement in procedures such as biopsy, local anesthesia, and fluid drainage. The game contains a virtual reality-based surgical simulator and provides a high degree of realism. The user interacts with the virtual world using a haptic device and a magnetic tracker as the controller. The game contains different game elements such as time-attack tasks, hints, and performance evaluation

tools. The thesis finally describes the experiments that were performed to validate its feasibility for training. The game described is similar to this project in terms of target audience and the objective of the game. It is however not a mobile application and requires specialized hardware. It is not certain whether this game is released anywhere or who has access to it.

2.5.2 SonoAccess 2.0 Mobile App

SonoAccess 2.0 Mobile App: Ultrasound Education at your fingertips [36] is a mobile application that contains educational content for medical professionals and medical students, see figure 2.9. The content is focused on ultrasound and is provided in the form of instructional videos, case studies, images and reference guides. The user may create their own personalized profile and state one or more specialities that is relevant to the information they seek. The user will then receive relevant content, related to each speciality, in the categories *How To* and *Cases*. The user may choose to download some of the content. The content may then be accessed from a personal *Download* folder when not connected to the internet. It is also possible to browse different types of content through a search function. The application aims to provide educational content for training in ultrasound interpretation as well as video introductions to medical procedures. *SonoAccess 2.0 Mobile App* does not aim to gamify the learning experience.

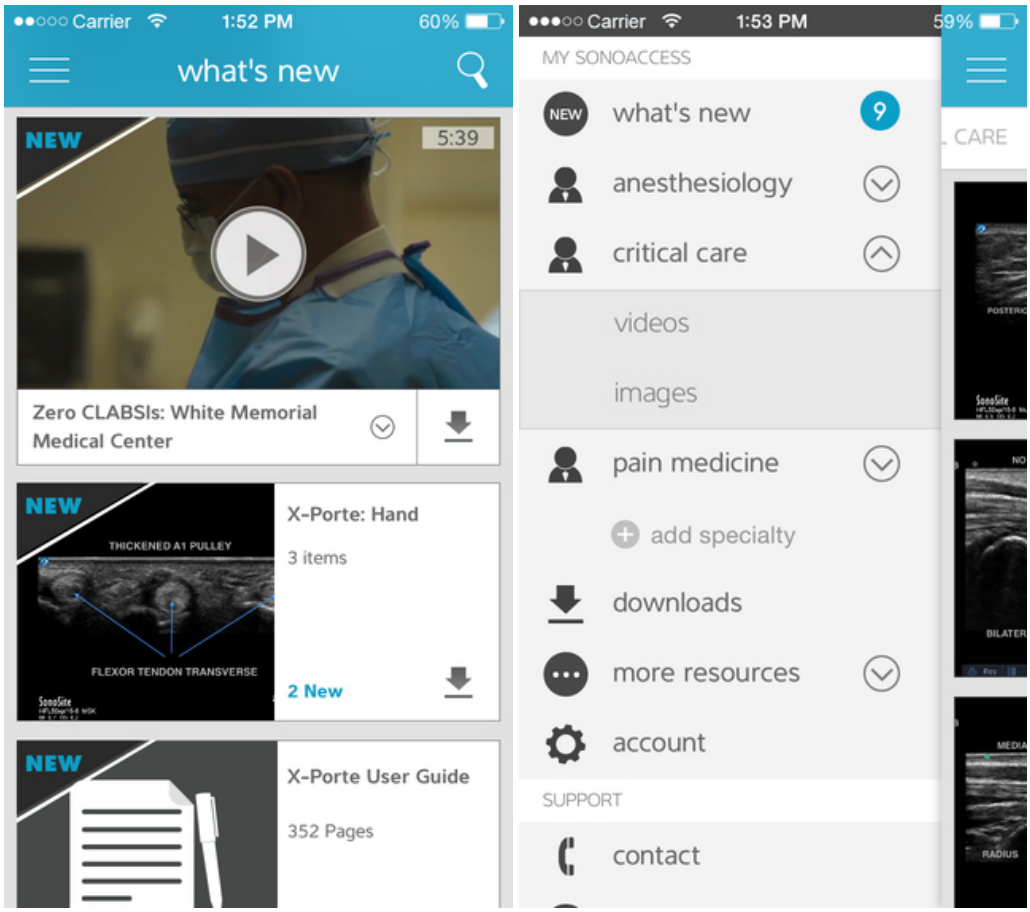


Figure 2.9: Screenshots from SonoAccess 2.0 Mobile App
Source: [36]

Chapter 3

Method

This chapter describes the approaches taken to answer the research questions listed in section 1.3. Section 3.1 introduces the available data and how it was aquired for this project, while section 3.2 illustrates how this project brings new ideas to current research.

In section 3.3 the methods used to answer RQ1 and RQ2 are presented. The section illustrating what needs to be considered, and what needs to be prioritized. Section 3.4 defines the requirements such a system should meet, both functional and non-functional. These requirements are then used to guide the development of the architecture in section 3.5.

Section 3.6 details how to organize the work between two developers. Finally, in section 3.7 a user test is planned that focuses on the research questions, and how they can be answered satisfactorily.

3.1 Data collection

The data available to this project was acquired by SINTEF and St. Olav's Hospital, both collaborating partners on this project.

The data consists of ultrasound images collected for research and development at SINTEF. SINTEF employees are the subjects of the ultrasound images, and they have signed releases for the use and publication of the data. The procedure of collecting the ultrasound material was executed by an anesthesiologist from St. Olav's Hospital. Both videos and images were made available to the project, as well as metadata in the form of anatomical annotations.

3.2 Novelty of approach

The use of ultrasound in femoral nerve blocks has many advantages, but interpreting the ultrasound images can be a challenge. If an educational game can be made by incorporating ultrasound images, there is potential to reduce the amount of formal training required. The application could be used as a teaching tool, which complements traditional teaching approaches. The application also gives students easy access to learning material, and the ability to take the material with them wherever they go.

A goal of the application is to make as easy and intuitive as possible. This in turn may create the opportunity for people to use the application in a casual setting. The application should require little effort to use, and should not require extra equipment. If this can be accomplished, time may be utilized that would otherwise not be spent doing anything in particular, i.e. while waiting at the doctor's office or riding the bus.

If the application is developed with a cross-platform framework it can be made available to most people without significantly increasing development time. The more people have access to the application, the more useful it would be as a teaching tool.

In addition to the basic functionality of the educational game, the concept creates the opportunity of making a self-sustaining application. The application may grow with time, and always contain relevant material. New material is continuously collected when regional anesthesia is performed at hospitals. If this material is hosted on a server, it could, in time, be automatically available in the application. Although this is an exciting prospect, it is unfortunately beyond the scope of this thesis.

3.3 Concepts

In section 1.3 there are several research questions outlined. This section will introduce concepts that will be used to achieve RQ1 and RQ2, namely how educational material can be embedded in the game and how to make people want to play the game.

3.3.1 Gameplay

Section 2.2 describes characteristics that may contribute to make an educational game entertaining. How these characteristics will be incorporated into the game is explained here.

The goal of the game will be to answer tasks correctly in order to receive points. It is a clear and practical goal. Several difficulty levels will be available, making it possible for players with little skill to experience a feeling of accomplishment, while still providing a challenge for more experienced players. The player can thus make the game appropriately challenging. The more difficult levels will force the player to perform tasks in quick succession. This creates uncertainty of reaching the goal, making the game more exiting. It also creates room for improvement, increasing the re-playability of the game. The points from each turn will be stored in a high score the player may strive to beat. The theory behind this strategy may be found in section 2.2.

Ultrasound images and videos will be the cognitive curiosity elements of the game. It is therefore very important that the player is curious about femoral ultrasound images. Considering that the target audience are future anesthesiologists, this should not be a problem.

3.3.2 Usability

When designing the appearance of the game it is important to make sure the design is user-friendly by making it intuitive and pleasing to the eye. A bad design may be off-putting for users. To accomplish this, guidelines from the standard *ISO 9241* [24] and the book "Designing the User Interface" [33] will be used.

Admirable goals

In *ISO 9241* [24] the usability of a system is described. The standard lays out several "admirable goals" that should be strived after, when developing a GUI. These goals may be summarized into the following list of more quantifiable characteristics [33].

1. Time to learn the task
2. Speed of performing tasks

3. Rate of errors by users
4. Retention over time
5. Subjective Satisfaction

The GUI will be designed with these goals in mind; easy to use, and with a pleasing appearance.

Organizing the display

When organizing the display it is desirable to avoid a cluttered appearance in terms of color choices, amount of colors, sizes of elements, number of fonts and grouping of the different elements. Consistency is important [35].

Efficiency is created by drawing the players attention towards the important parts of the screen [37]. The techniques that may be used for this includes high intensity colors and different fonts. As described in [37], only two intensities should be used, with high intensity elements used very sparingly.

By standardizing a theme across all pages the user will easily recognize their navigational options. Navigational options will be limited so that there is very little room for the player to make mistakes. The navigational buttons should be grouped and clearly marked so the player does not mistake their purpose [27].

Effectiveness

To increase the effectiveness of the user interface several things contribute. It is common to reference the "golden rules of interface design" described by Schneider [33]. Consistency is on this list and has been addressed above. Another item on the list is to *Reduce short-term memory load.* The user should not have to remember information from one page to another. If this is accomplished there is less to learn before playing the game, fulfilling the goals *time to learn* and *retention over time* [33].

3.4 Application requirements

The functional and non-functional requirements of Nerve Blocker are presented in table 3.1 and 3.2 respectively. The functional requirements define the features of the application, while the non-functional requirements describe im-

portant characteristics that contribute to the quality of the application, i.e. performance, userfriendliness, maintainable.

Each requirement has been given an ID. They are rated by how complex they will be to implement and how important they are to the application. Requirements with a high priority are a critical part of the application, while requirements with a low priority are less important.

Functional requirements

#	Functional Requirement	Complexity	Priority
FR1	The application should include a Point-and-Click game mode	Medium	High
FR2	The Point-and-Click game mode should include three games with different levels of difficulty	Medium	Medium
FR3	The medium level should contain an ultrasound image and ask a question about locating a structure	Medium	High
FR4	The easiest level should give the answer to the question asked	Medium	Medium
FR5	The most difficult level should have a time constraint	Medium	Medium
FR6	The most difficult level should award more time for correct answers	Medium	Low
FR7	The application should include a Video game mode	High	High
FR8	In the Video game mode, the player should locate the optimal spot for conducting femoral nerve block	Medium	High
FR9	The application should include an Annotation game mode	High	High
FR10	In the Annotation game mode, the player should annotate structures in an ultrasound image	High	High
FR11	The user should be awarded with points for correct answers in all game modes	Low	Medium
FR12	The application should include an instructional video	Medium	Medium

FR13	The application should run on both Android and iOS	Medium	High
FR14	The application should run on both phone and tablet	Low	Low
FR15	The user should be able to log into the application	High	Medium
FR16	The application should include a global high score list	High	Medium
FR17	An administrator should be able to update the content, via a server	High	Low
FR18	The user should be able to download content from a server	High	Low

Table 3.1: Functional requirements

Non-functional requirements

#	Non-functional Requirement	Priority
NFR1	The game should be fun to play	High
NFR2	The game should be educational	High
NFR3	The player should not be expected to have previous knowledge in femoral nerve block	Medium
NFR4	The application should be easy to use	High
NFR5	The application design should have a pleasing appearance	Medium
NFR6	The application size should be manageable and not cumbersome to download	Low

Table 3.2: Non-functional requirements

3.5 Architecture

A goal of this thesis is to reach as many people as possible. To achieve this with limited time and resources, a cross-platform framework, Qt, will be used. Qt is already used in other development projects at SINTEF, one of the collaborating partners on this project. Using Qt will make it easier for the partners to maintain the project in the future. Furthermore, using qt does also mean that the application may be deployed on desktop operating systems, such as OS X

and Linux in addition to mobile operating systems. This enables the developers to create the system without having to deploy the application to a smartphone frequently, which may be time-consuming. A more in-depth look at Qt can be found in section 2.4. This section describes the two programming concepts MVC and Stack that will be used in the architecture of the application.

3.5.1 Model-view-controller

model-view-controller (MVC) is an architectural pattern used for organizing software. Though there are several slight variations of MVC the one depicted in figure 3.1 will be used for this prototype.

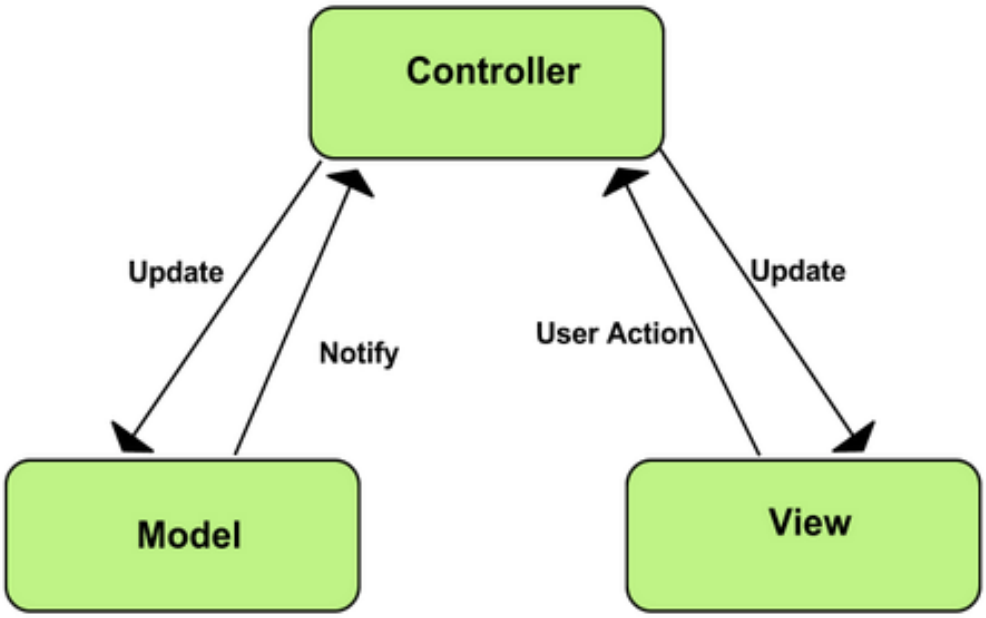


Figure 3.1: A diagram representing the model-view-controller design pattern.
Source: [21]

In MVC, the *model* represents all the internal data with procedures for writing and reading this data. The *view* is the software displaying internal data to the user. The *controller* provide communication between the model and the view. When the user performs an action, typically pressing a button in the view, the controller is notified, interprets the action and updates the model. The controller then tells the view that the model has changed and that the displayed

data must be updated. [11]

The purpose of implementing MVC is to create software that is organized and easy to maintain. By implementing MVC correctly it is possible to reuse the model software for different views, and even possible to use two different views on the same model at the same time.

In this prototype, both the model and the controller will be implemented in c++.. The Qt framework is highly optimized for the MVC pattern and large parts of what would be the controller is automated through signals and slots (see section 2.4.1). The rest of the controller will be implemented as methods to the model implementation. The view will be implemented in QML.

3.5.2 Stack

The view will be implemented using the QML type StackView, see figure 3.2. When the user makes navigational choices in the application, a QML component is pushed onto the stack. At any time it is the QML component at the top of the stack that is visible to the user. To return to the previous view, the topmost QML component is removed from the stack to expose the underlying file. In the prototype implementation of this project the stack will have a maximum depth of 3 and a minimum of 1, as figure 3.2 depicts.

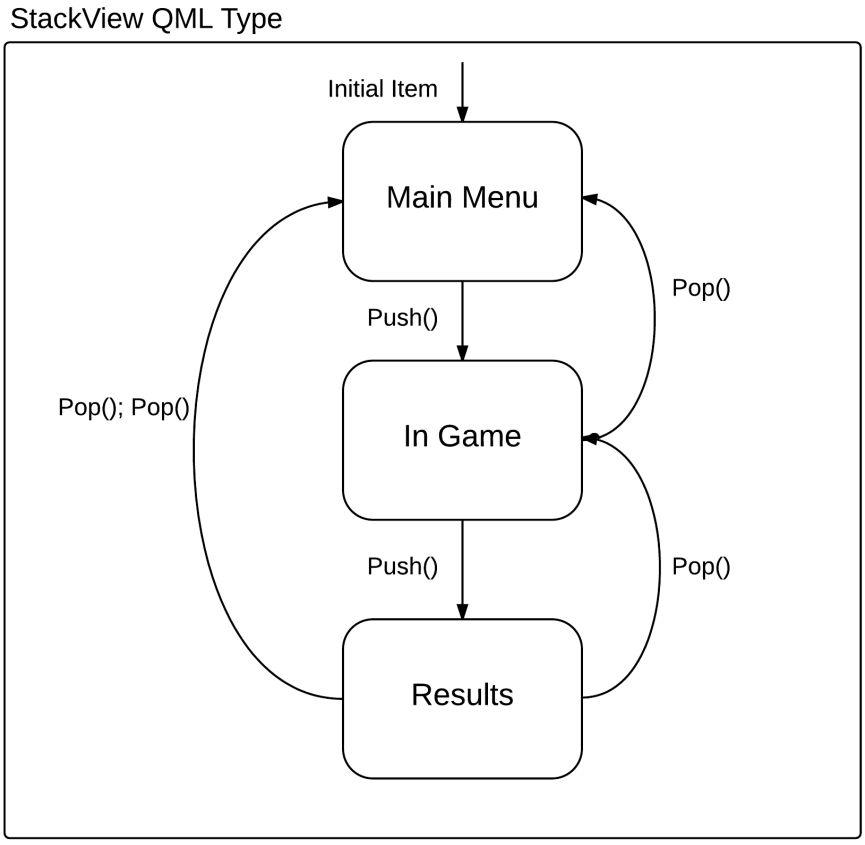


Figure 3.2: A simplified diagram of the way QML content is controlled.

3.5.3 System flowcharts and game design

Figures 3.3 and 3.4 shows how the user will interact with the application.

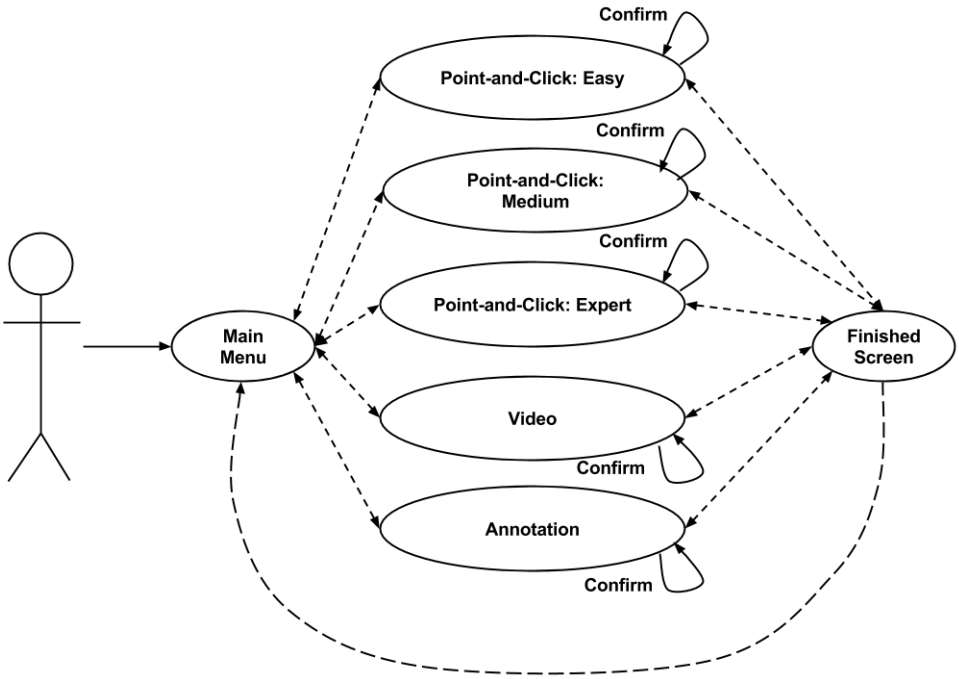


Figure 3.3: A system flow chart of the user's interaction with the game components.

From the main menu the user should be able to choose between the five different game modes. When the game is completed the user is taken to the summary page. The user can move between these three states with navigation buttons provided in the application.

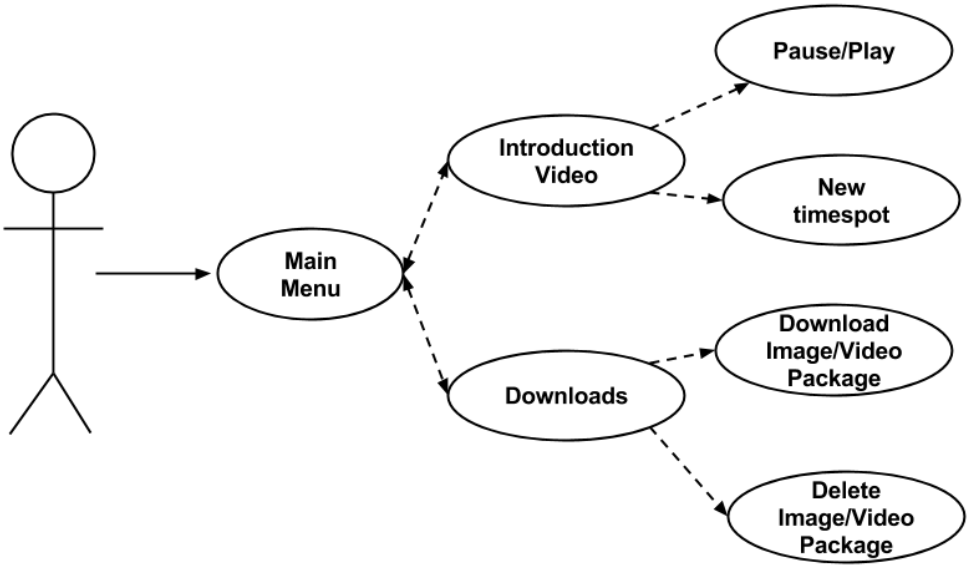


Figure 3.4: A system flow chart of the user's interaction with the Instructional Video and Downloads.

From the main menu the user may also choose to watch an instructional video or download more content to the games, i.e. more images and videos. The content is downloaded from a server and stored on the device, with the option of deleting it again. By letting the user download additional content, the application may be kept small while still providing sufficient teaching material.

3.6 Development process

During the development of this project, no strict development process will be followed. This is due to the fact that the project only has two programmers, and a development process would introduce too much overhead. The development was instead focused on first developing a working prototype, and then iteratively adding more functionality. This may also be described as an agile development pattern. To make sure the development is on the right track, several informal user-tests will be executed. The tests measure the usability and entertainment value of the game on fellow students at NTNU and not the target audience.

Towards the end of the project, focus will be moved from software development to formal testing. The formal test will be used as a definite answer to the research questions from section 1.3. To keep track of goals, workload and development tasks the website *www.Trello.com* will be used. The project will be developed using Git to share source code between the developers as well as to provide version control. All other project files will be shared through Google Drive.

3.7 Evaluation

To find out how great the educational value of the application is, and to which extent the users want to use it, a formal user test will be conducted. The results from the test will determine if RQ1 and RQ2 have been answered. The user test will consist of several parts: The system usability scale (SUS), a usefulness questionnaire and a proficiency test.

3.7.1 System usability scale

The System Usability Scale is a tool used to measure and evaluate the usability of a system [26]. It consists of 10 statements about the system. The participants score each statement with one of five response options, ranging from "Strongly Agree" to "Strongly Disagree". A SUS score is then calculated representing a composite measure of the overall usability of the system being studied.

SUS has the benefit of being able to effectively differentiate between usable and unusable systems and yields reliable results even on small sample sizes. It is not diagnostic, however, meaning that one cannot decipher what is wrong with the system, only that something might be wrong.

The respondents should fill out the SUS form right after having used the system and before any form of debriefing or discussion about the system. All items on the questionnaire have to be answered.

The SUS form used in the user test can be found in appendix A.

3.7.2 Usefulness questionnaire

There will be an additional questionnaire to the SUS questionnaire, with questions concerning the usefulness of the application in regards to revision and

learning new material. The questionnaire will also gauge if the player had fun and give general feedback on possible improvements.

The questionnaire can be found in appendix B.

3.7.3 Proficiency test

In order to determine whether the application may help users increase their knowledge and experience in the femoral nerve block, some of the participants will perform proficiency tests. One before, and one after having tried the application. Ideally, the proficiency test should consist of an actual femoral ultrasound procedure, where the testers control the ultrasound technology. This is infeasible due to limited resources. Instead the participant will be presented with a femoral ultrasound image on a paper. They will then be asked to annotate 5 different anatomical structures in the image, using colored pens, with each structure having an assigned color. The performance of the participant will be scored for each image based on how correctly annotated it is.

3.7.4 Test participants

The participants of the user test are employees at SINTEF Department of Medical technology. They do not belong to the target audience of the application, though some of the participants do work with Regional Anesthesia through their involvement in the RAsimAS project [34]. The actual target audience consists of students training to become Anesthesiologists, but this group of people is very small and its members are difficult to recruit for user testing.

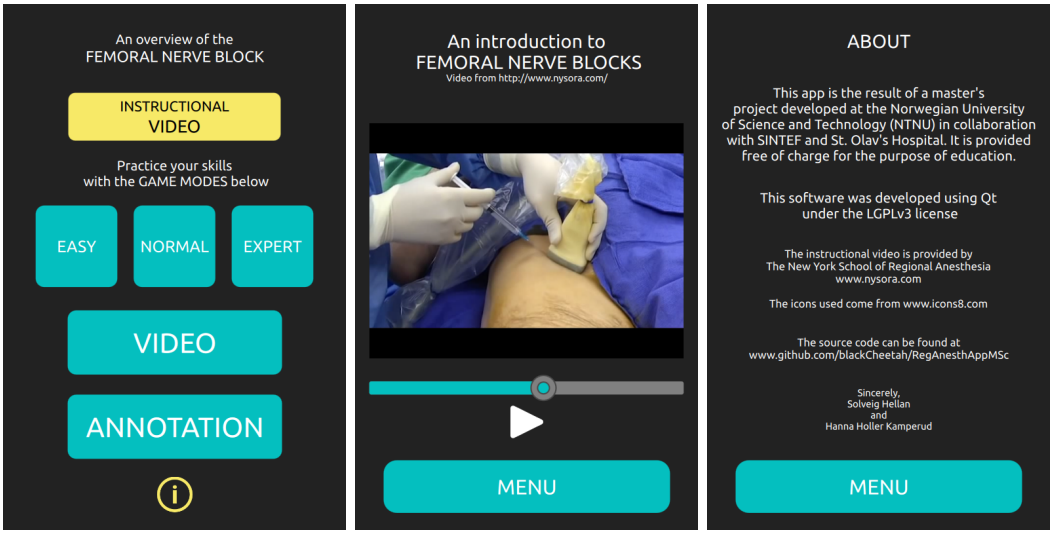
Chapter 4

Implementation

In chapter 4, the implementation details of the application, and the evaluation performed on it, are described. Section 4.1 describes the design decisions made and presents the user interface of the application. Next, section 4.2 goes through the game mechanics of the application. In section 4.3 both high and low-level software implementation details are provided, and finally, section 4.4 explains how user tests were performed on the application.

4.1 Game design

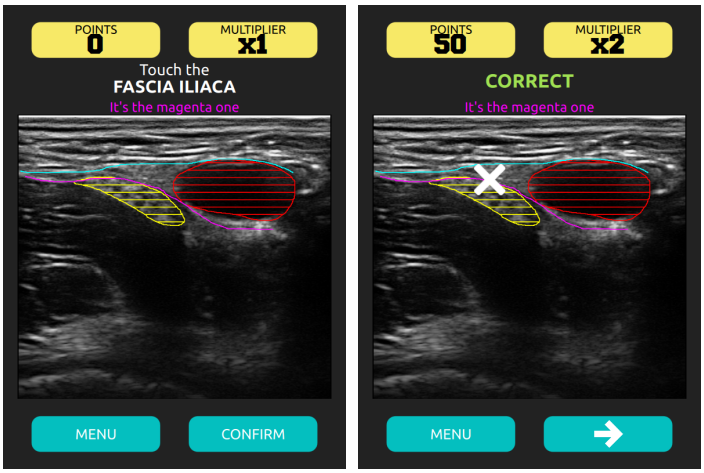
This chapter presents the design of the application, and explains some of the design choices made. Figure 4.1 shows the main menu and the two parts of the application that are not a part of the game modes, the instructional video and the *about* page. The about page displays information about the application to the user.



(a) Main menu (b) Instructional video (c) About page

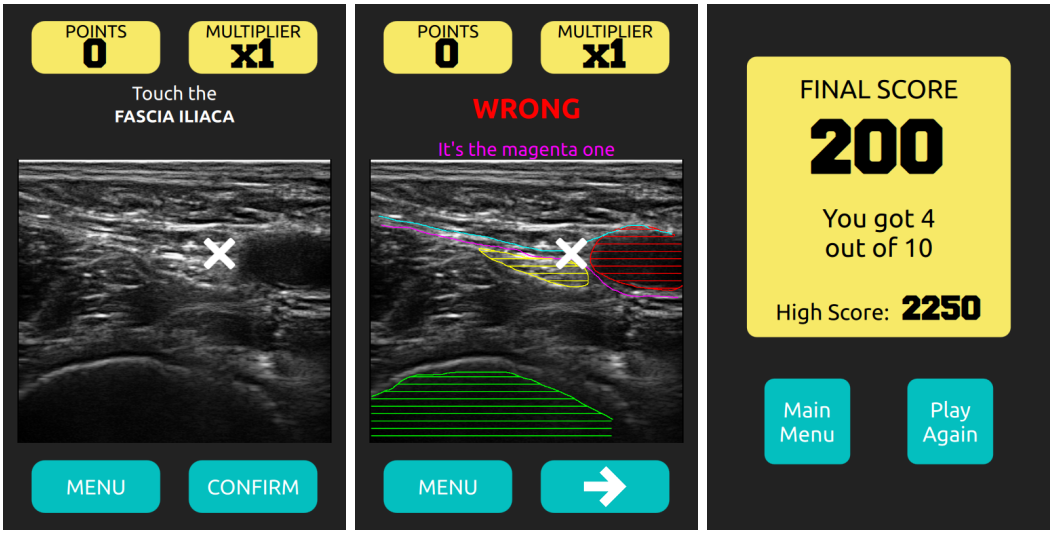
Figure 4.1: The main menu and informational pages

Figures 4.2, 4.3, 4.4, 4.5 and 4.6, shows the five different game modes in the order they appear in the main menu. The figures show how the game modes appear both before and after an answer has been given by the player, as well as a summary page with the player's results. Section 4.2 describes how the different game modes are played.



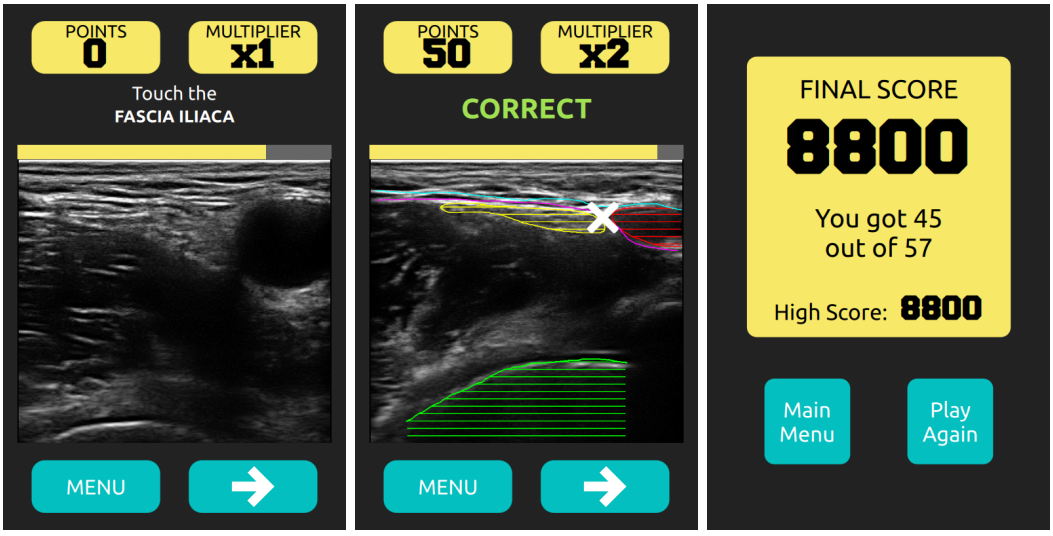
(a) Before answer is confirmed (b) After answer is confirmed

Figure 4.2: Easy game mode



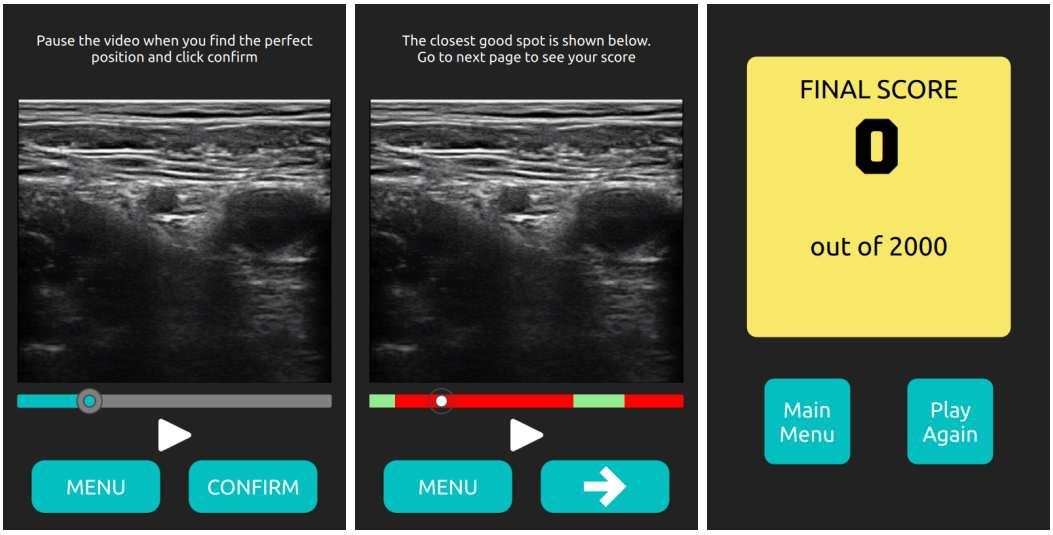
(a) Before answer is confirmed (b) After answer is confirmed (c) The summary page

Figure 4.3: Normal game mode



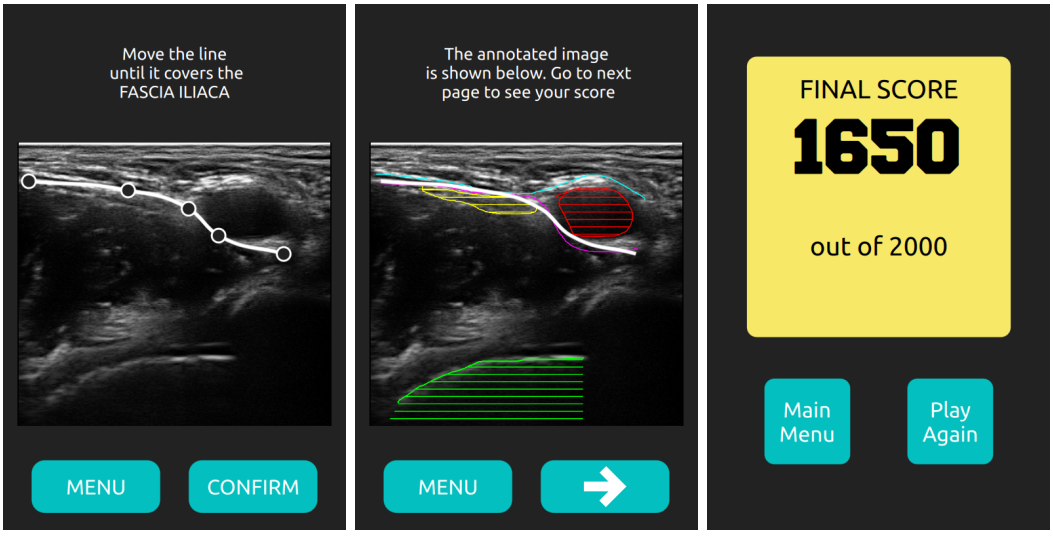
(a) Before the task is answered (b) After the task is answered (c) The summary page

Figure 4.4: Expert game mode



(a) Before answer is confirmed (b) After answer is confirmed (c) The summary page

Figure 4.5: Video game mode



(a) Before answer is confirmed (b) After answer is confirmed (c) The summary page

Figure 4.6: Annotation game mode

To achieve consistency in the design, elements with similar meanings or actions are identified by their color and placement. Buttons are placed next to

each other at the bottom of the screen, while information is grouped together at the top of the screen. Consistency will also be achieved through a limited color palette. Two main colors, blue and yellow, have been chosen. Buttons are displayed in blue, while information is displayed in yellow. In addition there are varying gray colors, because the ultrasound images are inherently black and white, and heavy contrasts should be avoided.

The theme described is repeated across all pages, helping the user recognize their navigational options. Navigating in the application is simple, as there are only three states the player can navigate between. These are the main menu, one of the five different game modes, and a result page. From the game it is possible to navigate back to the menu, while from the result page it is possible to navigate back to the game or to the menu.

Keeping the design consistent and the navigation simple, can minimize the number of mistakes the user makes. Error prevention is also enforced by implementing a confirm button in most of the game modes. The player must confirm the answer given in a task before the answer is registered and assessed. This gives the player a chance to correct their answer.

4.2 Game mechanics

In this section the game mechanics of the application are described. The goal of the gameplay is to fulfill several of the functional requirements listed in section 3.4, as well as a few of the non-functional requirements.

Three game modes were implemented:

- Point-and-Click
- Video
- Annotation

By providing a diverse selection of game modes, the user may practice a wider range of skills needed when practicing Regional Anesthesia.

Point-and-Click

The Point-and-Click game mode provides the basic knowledge of the most important anatomical structures in the femoral nerve block. The player is presented with a task that consists of an ultrasound image and a question. The

player is asked to identify an anatomical structure, such as the femoral nerve or the femoral artery. More specifically, the player is asked to touch the part of the image where they think the structure is located and is awarded points if the question is answered correctly. The player is also shown a correctly annotated version of the image in the task to provide the means for the player to learn and improve.

The player receives points for answering a task correctly. In addition there is a *point multiplier*. The multiplier increases by one for each correct answer and resets for every wrong answer. The number of points received depends on the multiplier. A higher multiplier value gives the player more points. This increases the stakes for the player. If the multiplier is high then getting a question wrong has more dire consequences than when the multiplier is low, creating excitement.

There are ten tasks the player needs to answer before they receive their final score.

The Point-and-Click game mode includes three difficulty levels, namely *Easy*, *Normal* and *Expert*. The Normal level works as described above and is pictured in figure 4.3.

The Easy mode acts as a tutorial level and can be seen in figure 4.2. The correctly annotated image will be visible from the start, together with a helping text, giving the location of the structure in question. This level makes sure the player does not need previous experience in order to play the game.

Finally, the Expert level adds a time constraint to the tasks, see figure 4.4. The player is shown a progress bar and has to answer as many tasks a possible in the time alloted. If a question is answered correctly the player earns additional time. Challenge is an important aspect to making a game fun to play, as explained in section 2.2. This level provides the player with an extra challenge, as the achievement of the goal is uncertain. The player can always be faster and get a higher score.

Video

The Video game mode, seen in figure 4.5, focuses on the *scanning skills* mentioned in section 2.1.3. Scanning skills are needed when an ultrasound technician attempts to find a good view to use when performing a femoral nerve block.

The game mode displays a video to the player as well as a progress bar and

a pause/play-button. The video shows a scan performed on the area of the femoral nerve. The player is asked to watch the video and pause it at a position where they believe the view is appropriately positioned to perform a femoral nerve block. When the player has confirmed their answer, the video's progress bar will show the positions deemed appropriate as well as the positions deemed inappropriate for performing a femoral nerve block. The feedback will be displayed by coloring the bar green to indicate good positions, and red to indicate bad positions. The player is awarded points if the position they chose is in the recommended(green) area. When the player has been shown the answer they may re-watch the video, and learn what a good view implies.

Annotation

The Annotation game mode, see figure 4.6, is similar to the Point-and-Click game mode. The player is shown an ultrasound image and is asked to locate a certain structure in the image. However, in the Point-and-Click game mode, the player only needs to know one point the structure passes through to get a full score. In Annotation, the entire structure must be covered with a curve that the player controls. The curve can be modified using five movable sliders placed along the curve. When the player has confirmed their annotation, the solution is displayed. The player is awarded points based on how closely the answer resembles the solution.

Instructional video

The application includes an instructional video that shows how a femoral nerve block is performed. In addition to the Easy game mode explained above, this will contribute to the player not having to have previous experience in the field in order to play. The instructional video can be seen in figure 4.1b

High score

In some game modes, the highest score the player achieves is saved and is displayed whenever the player receives a new score. This is done to motivate the player to strive to beat their high score.

4.3 Software design

4.3.1 Software overview

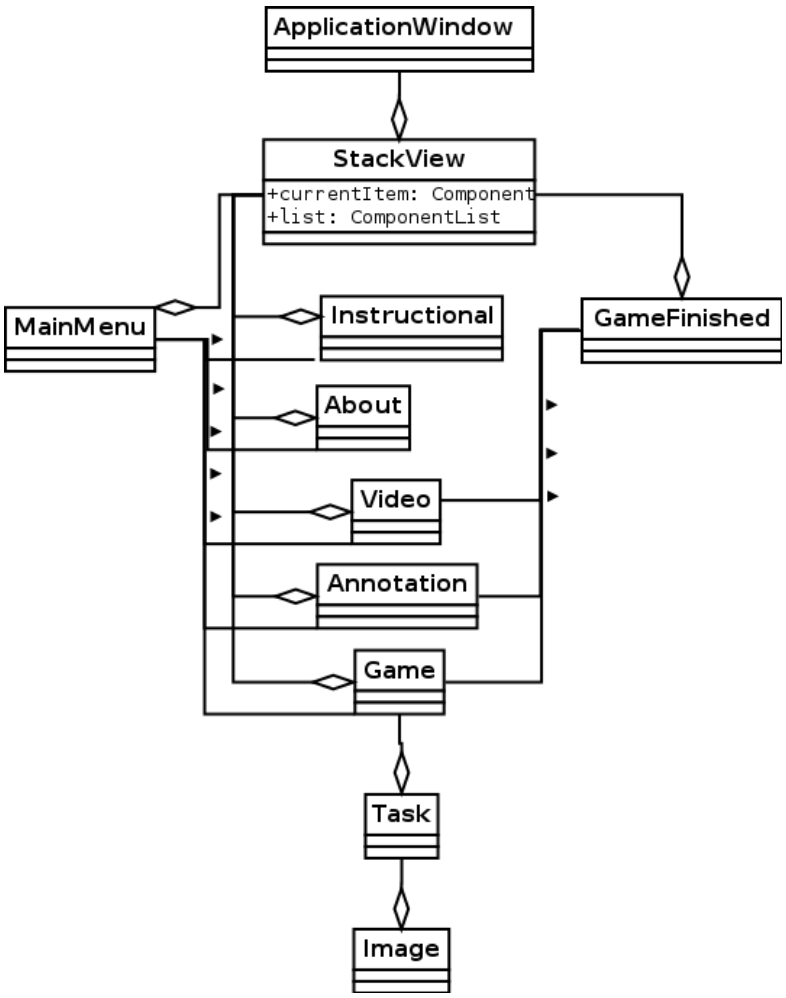


Figure 4.7: A simplified diagram showing how the QML components interact

The software development of the prototype was implemented in Qt, the cross-platform framework detailed in section 2.4.

In figure 4.7 a simplified overview of the QML elements are illustrated. All QML components are organized in a hierarchy.

ApplicationWindow provides an application window and all QML files are ancestors of this element.

StackView the main control in the QML tree.

MainMenu is a QML type created for this prototype and it is the first item loaded by the `StackView` component.

When user input is detected inside the `MainMenu` component, a signal is sent back to the `StackView`, which pushes or pops appropriate items onto itself. The top element in `StackView` is the element that is currently displayed to the user.

Game the implementation of the Point-and-Click game mode.

Video the implementation of the Video game mode.

Annotation the implementation of the Annotation game mode.

Instruction the implementation of the instructional video.

About the component displaying information to the user about this project.

GameFinished the implementation of the summary screen giving feedback to the user on their performance. This page gives the user the option to return to `MainMenu` or play the same game mode over again.

When game modes end, they send a signal to `StackView`, making `StackView` push the `GameFinished` component on top of the stack. The pages that are not game modes can only navigate back to `MainMenu`.

When the user presses a game mode button in `MainMenu`, the `StackView` calls a C++ method `newGame`. `NewGame` is a `Q_INVOKABLE` which is why it can be invoked from QML. This method creates a new game of the same type that the user indicated. The values from C++ are then updated automatically in the QML code through `Q_PROPERTY`'s. `Q_PROPERTY` lets QML read, write and/or listen to changes on the C++-variables exposed.

A simplified class diagram of the C++ implementation is shown in figure 4.8.

GameHandler is the class at the top of the architectural tree. It contains the members `game` and `highscore`, and methods to handle these.

Game initializes the `game` in `GameHandler`, and exposes some of its members to QML through `Q_PROPERTY`. Contains the member `currentTask`.

Mode is an enumeration class which lists the available game modes.

Task exposes additional properties to QML needed for the Point-and-Click game mode. i.e. which organ the QML task component should ask after, image paths to display and the score on individual tasks.

TaskVideo exposes additional properties to QML needed for the Video game mode.

TaskAnnotation exposes additional properties to QML needed for the Annotation game mode.

Depending on the type of `Mode` a `Game` is initialized with, different values for the `currentTask`-member in `Game` are created. If the mode is `Mode::VIDEO` then `currentTask` is initialized with `TaskVideo` instead of `Task` or `TaskAnnotation`.

Like most C++ projects, execution starts in the main function. main.cpp can be seen in listing 4.1 and contains the function responsible for connecting the C++ and QML source code. This can be seen in lines 12 through 15. Line 12 initializes an instance of the `GameHandler` object. This object is then registered into the runtime context of the QML code in line 13. These two lines give QML access to everything the `GameHandler` class has to offer except the two enumerations `Mode` and `Organ`. These are registered as new QML types in lines 14 and 15. The enums are not actually necessary in the QML but they are imported for the convenience of writing the enum labels instead of integers in QML.

```
1  #include "gamehandler.h"
2
3  #include <QApplication>
4  #include <QQmlApplicationEngine>
5  #include <QQmlContext>
6  #include <QtQml>
7
8  int main(int argc, char *argv[])
9  {
10     QApplication app(argc, argv);
11     QQmlApplicationEngine engine;
12     GameHandler gamehandler;
13     engine.rootContext()->setContextProperty("gamehandler", &gamehandler);
14     qmlRegisterUncreatableType<Organ>("UllApp", 1, 0, "Organ", "Organ is uncreatable");
15     qmlRegisterUncreatableType<Mode>("UllApp", 1, 0, "Mode", "Mode is uncreatable");
16     engine.load(QUrl(QStringLiteral("qrc:/main.qml")));
17
18     return app.exec();
19 }
```

Listing 4.1: The source code for main.cpp. This code is responsible for exposing the C++ code to the QML code.

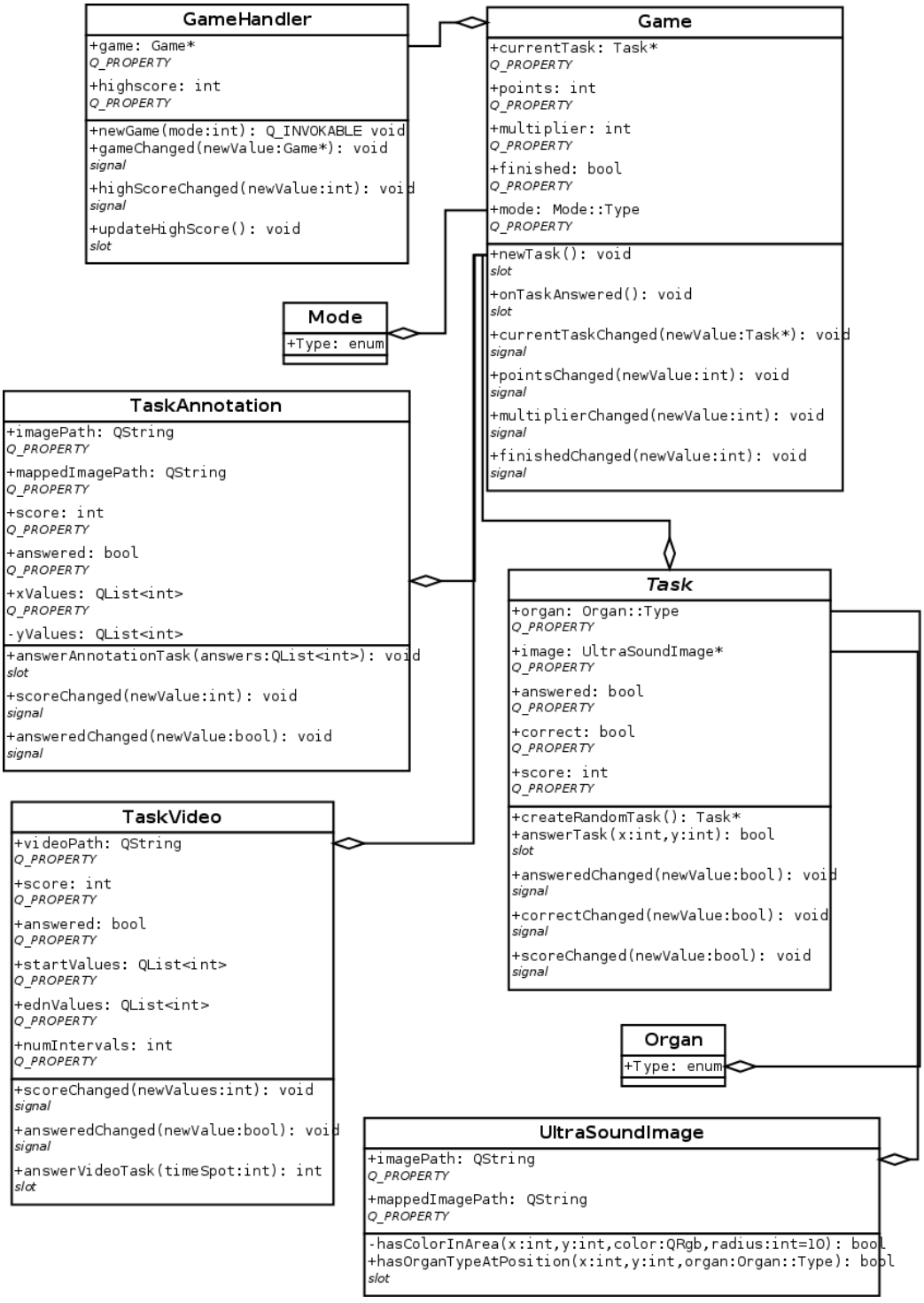


Figure 4.8: A simplified class diagram showing how the C++ classes interact

4.3.2 Game component implementations

In addition to the overview of the architecture given above, these are low-level implementation details of some of the individual components that are of interest.

Data

The data needed for the gaming content consists of ultrasound images and videos. The images are approximately 350 kB in size and the videos approximately 9 MB. To make the images available to the game they are compiled into the binary files of the application. This solution has the advantage of making some gaming content available straight after download and installation of the application while still keeping the application a manageable size. The current size of the application is 46.9 MB on iOS and 42.2 MB on Android. In order to support a large number of additional images, a different approach would have been necessary. During this project, however, no more data was available, so this issue was not explored further.

The ultrasound videos used by the application are much larger in size than the images, and are therefore not compiled into the binary files of the application. The video files are compressed versions of the original files, transforming them from approximately 40 MB to 9 MB. More compression affected the quality of the videos too much, compromising the educational value. The videos are hosted on a server and streamed to the application when needed. This means that an Internet connection is required for the video content in the application.

Metadata

To implement the game mechanics mentioned in section 4.2 the data also requires metadata. First and foremost, all the images need annotations, preferably produced by a medical professional. These are displayed as feedback for the user. The same annotations are also used by the code to determine if the user has clicked the right area of the image. This is created by adding a second picture as metadata to the original ultrasound image, both may be seen in figure 4.9. The annotation map is mostly transparent except for the few annotations. When giving feedback to the user the QML code simply puts both pictures on top of each other, creating an annotated ultrasound image for the user to learn from. This metadata image is about 8 kB large making a negligible

impact on the application file size. The annotation map is also used when giving the user points after answering a task. A coordinate is sent from QML to the C++ to indicate the user's answer to the task. The coordinate is checked against the map to see if the correct color can be found within a radius of 10-15 pixels. It is therefore very important that the map is annotated with the correct colors as listed below:

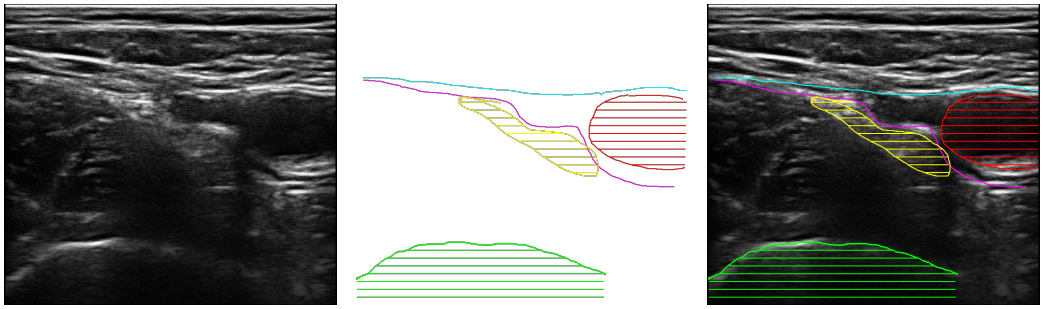
#FF0000 red

#FFFF00 yellow

#00FF00 green

#FF00FF magenta

#00FFFF cyan



(a) An ultrasound image (b) An annotation of the same image (c) 4.9a and 4.9b combined

Figure 4.9: This figure illustrates how the ultrasound images are presented to the player.

The last metadata needed for the Point-and-Click game mode is a boolean value that indicates whether or not the femur is visible in the image. Other than the femur all anatomical structures are visible in every image. This prevents the game from asking the player to identify the femur in an image that does not have one.

For the Annotation game mode a new set of metadata is required. The annotation is created by the use of Bezier curves which are easy to create via the Canvas QML type. The user is able to manipulate five *sliders* by moving them along the Y-axis. The restriction is in place to make it easier for the application to know if the curve is in the right location. The metadata stored is a set of coordinates corresponding to the five sliders the user can manipulate. The X-values are used to position the initial elements together with a generic Y-value

all the sliders are initialized with. The user then slides the curve into place and sends the suggested solution back to be compared with the correct Y-values in the metadata.

In the Video game mode, the player is asked to pause the video at an appropriate time. The metadata necessary to implement this is stored in the form of "correct" and "wrong" time intervals. The metadata is used to determine if the player has answered correctly, and to give the player feedback on which other time spots would also be appropriate.

4.3.3 Bugs and unimplemented features

Video on iOS

The only known bug that remains in the prototype is a bug that exists for iOS. When the user suspends the application by pressing the home button, the video element in Qt resizes to the source size, pixel by pixel. On small or low-resolution screens, the video becomes very large, while on higher-resolution screens, the video becomes small. The bug seems to originate from somewhere in the Qt framework, and not from the project source code.

The bug is also present inside the game, when the video stops and restarts. This happens often in the Video game mode, as the video is set to repeat itself. To circumvent the issue, a timer in the QML code checks the progress of the video and makes sure it never reaches end-of-file. However, no circumvention has been found to prevent the error when the home button is pressed.

Bugs are one of the main reasons applications are rejected by App Store. It is unlikely that the application, in its current state, would be accepted for publication, without removing the video content. As Qt is open-source it is possible to fix the bug without waiting for official institutions. However, since new Qt releases become available several times per year, a fix might be available soon.

Login and Global High Scores

There are several ways to implement login capabilities. In this project, FaceBook login was attempted. It is also possible to implement login through Qt, if the project has its own server back-end.

The reason Facebook login was not completed in this project, was because there was no official Qt support for OAuth, the protocol used by many compa-

nies to secure remote login attempts, including Facebook. The Facebook SDK for connecting Android applications is different to the one used to connect to iOS. Facebook login therefore requires two implementations, one per operating system.

A global high score list was also not implemented due to the missing login functionality. The high score list depends on the user profiles provided by login.

Downloadable content

To provide the user with enough content to practice ultrasound interpretation on, a server back-end was planned. In addition, a server application would be available to enable non-programmers to add content to the server in the format needed by the game. Due to time constraints, this was not implemented. Only the user interface was designed, and can be seen in figure 4.10. This figure also shows the proposed location of a Facebook login button and the user name of the logged in person.

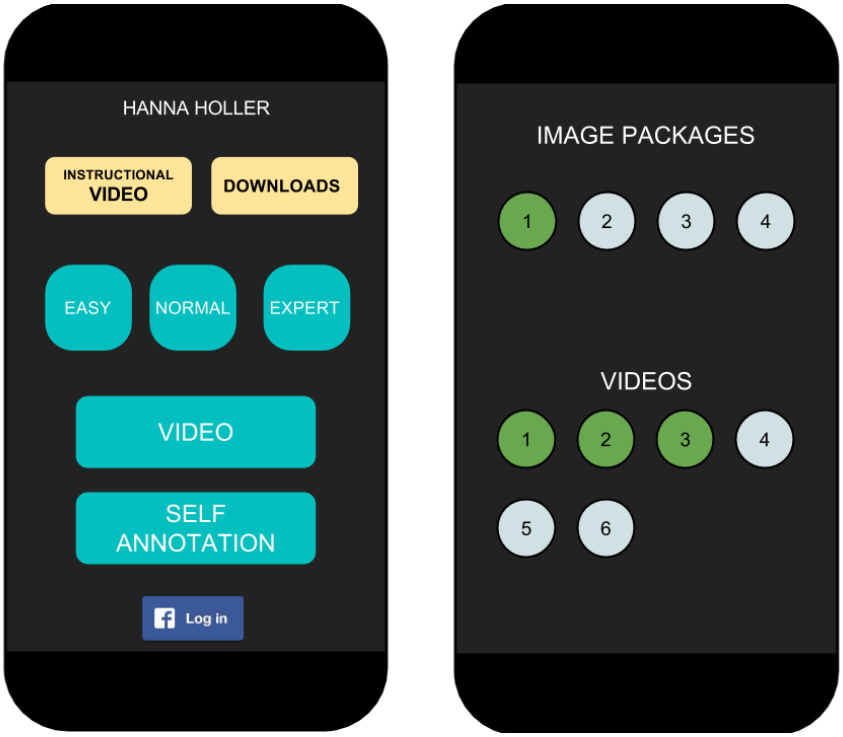


Figure 4.10: Proposed design of the game menu with the Downloads button and downloads pages

4.3.4 Operating systems and supported devices

The application is supported by both iOS and Android devices. It has been tested on several versions of Android and iOS, including both smart phones and tablets.

Most of the metadata is hard-coded into the source code of application. This is because the application was developed for both Android and iOS. Local application data is harder to store since it is done differently for each OS. This section of code would have to be tailored to each OS one wants to support.

To make the application ready for publication on App Store and Google Play, an additional informational page has been added to the application. According to the license LGPLv3 used by Qt it is mandatory to inform the user that the LGPLv3 license has been used. This requirement is fulfilled by the *About*-page created just for this purpose. In addition, the page credits the institutions that have contributed content and designs, as well as informing the user where the source code of the project may be found.

In order to publish the application on Google Play it has to be signed with an RSA key pair to certify who the author is. Section 2.3 describes Android publishing in more detail.

To publish the application to Apple's App Store it needs a provisioning profile that contains an App ID. At the moment the application has a Wildcard App ID, but an explicit App ID is needed if the application supports In-App Purchases or Push-Notifications. Because the application uses neither of these, an explicit App ID is not necessary.

4.4 Evaluation

The user test took place at SINTEF, during a weekly meeting, where the topic was the Nerve Blocker application. A total of 15 people participated in the test and five of these took the proficiency test.

A presentation of the application was held before any testing took place. Ten of the participants were present at the presentation and all the participants who took the proficiency test were present. The presentation included a description of the objective of the master thesis, an introductory video to the femoral nerve block and a walkthrough of the application.

A subset of the testers participated in the proficiency test in order to determine their level of knowledge and proficiency in the field.

Subsequently, all the test participants were allowed to try the application. The application was installed on two Android tablets and two iPads. The participants performed the user test four at a time, due to time constraints. They were asked to try all the five different game modes in the game, but were otherwise free to choose which order they would like to play the games, and how much time they would like to spend on each game mode. When they had played all the game modes they were asked to fill out the usefulness and SUS questionnaires.

The participants who performed the proficiency test had access to the application in the week following the user test, and were requested to use the application on occasion. Approximately a week after the user test they redid the proficiency test.

Although, user tests should be performed in a controlled environment, with no introduction of the application, the above format allowed the project to recruit a great number of participants with a relevant background, despite not belonging to the target audience.

There were no technical issues or crashes with the application during the test.

Chapter 5

Results

In this chapter the results from the various evaluations will be presented. First, in section 5.1, a SUS score is calculated from the SUS questionnaire. Then the feedback received from additional questions about usefulness are presented in section 5.2. In section 5.3 the results from the proficiency test are included. Finally, the feedback recieved from a teacher of ultrasound-guided regional anesthesia is included in section 5.4.

5.1 SUS score

When interpreting the SUS scores, the score of each of the ten items are summarized. All the individual item scores range from 0 to 4. For odd numbered items the score equals the postion of the scale minus 1. For even numbered items the score is 5 minus the position of the scale. The sum is multiplied by 2.5, yielding an overall value of system usability. A SUS score above 68 is considered above average [26].

Table 5.1 shows the results from the SUS survey. The application scored 85,25 points out of 100. Using the Adjective Rating Scale [4], this score corresponds to the rating “Excellent”.

#	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**

Table 5.1: Application SUS Scores

5.2 Usefulness

The questions from the usefulness questionnaire are divided into three segments. In the first segment the participants were asked to agree with statements on a scale, while throughout the rest of the questionnaire participants were asked to write a response.

The complete set of answers can be found in appendix C.

5.2.1 Perceived usefulness

The results of the usefulness questionnaire is shown in table 5.2. The feedback is very positive, both toward the learning potential and the participant's willingness to use the application. In questions 1 through 5, the participants were asked if they thought the application had potential to teach. The average response was between "Agree" and "Strongly Agree". When asked if the participants would actually use the application themselves, in questions 6 through 8,

the response was similar, except for question 8. Here, the participants were a little less enthusiastic and had an average answer between “Neutral” and “Agree”.

#	Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Learning Outcome						
1	I think the application made me learn how to interpret ultrasound images	0 %	0 %	6 %	66 %	26 %
2	I think it is an advantage to use the application before relevant lectures in ultrasound interpretation	0 %	0 %	6 %	40 %	53 %
3	I think regularly using the application can help me learn the material	0 %	0 %	6 %	53 %	40 %
4	I think it is wise to use the application to revise the learning material	0 %	0 %	0 %	46 %	53 %
5	I would recommend this application to a friend	0 %	0 %	6 %	33 %	60 %
Range of use						
6	I would use the application before I have lectures in femoral ultrasound interpretation	0 %	0 %	20 %	33 %	46 %
7	I would use the application to learn the material better	0 %	6 %	6 %	26 %	60 %
8	I would use the application when i have extra time on hand	6 %	20 %	53 %	20 %	0 %

Table 5.2: Perceived usefulness of application

5.2.2 Game mode feedback

In the questionnaire the test participants were asked which game mode they preferred and why. Point-and-Click mode was the most popular game. This was somewhat due to its natural progress from easy to expert. Most of the participants were not familiar with locating structures in ultrasound images, and expressed that the Easy mode was a good introduction to understanding the femoral ultrasound images. They were positive to the progress from an easy mode to more difficult ones, and thought it was helpful giving a natural progression to their learning.

The questionnaire also asked the participants if they ever felt they got “carried away” when playing. Most of the participants answered yes in this regard. Some of the participants expressed that this was due to the time constraint in Expert mode.

Video and Annotation scored similarly in popularity. Some liked the more practical setting of the video mode, and some felt it was the most medically relevant mode. Finding the right view is essential when performing ultrasound-guided anesthesia. Others preferred Annotation because it required more interaction.

Many of the participants appreciated that the solution was revealed after answering each question.

5.2.3 Improvements

In the usefulness questionnaire, the participants were asked what they thought could improve the application and what functionality they thought was missing from the application. They were also asked what game mode they like the least and why. The following is a summary of that feedback.

Names

A few participants expressed confusion over the names of the game modes. The mode “Easy” was too easy, and should rather be called “Practice” or “Tutorial”, and does not necessarily need a score. The names of the modes “Annotation” and “Video” could be more descriptive, e.g. “Find/Place anatomical structure” and “Find the right imaging plane”.

Expert mode

The timer in this mode should pause whenever the solution is showing. That is, after the answer has been confirmed and before the player navigates to the next task. This mode also required too many unnecessary button pushes, considering the limited time, i.e. two button pushes should be reduces to one.

Annotation

One participant wished that the sliding buttons could be moved sideways, as well as up and down.

Video

It was difficult to understand the area of application for this game mode, and it should have a more elaborate description.

Score

The score should be based on the distance between the structure and the area the player choses, instead of only being correct or incorrect. This is especially relevant for the fascia iliaca and the fascia lata. One participant found what the "Multiplier" entailed to be unclear. Another participant thought there should be a global high score.

Progress

In the first two game modes, Easy and Medium, there are 10 tasks in each game. Initially, the player has no way of knowing this. Several participants suggested that the user should know their progress in the game, either through a task counter or through percentages.

Menu

The layout of the menu should more clearly differentiate between the 3 different game modes: Point-and-Click (with its different degrees of difficulty), Annotation and Video.

New material

One participant suggested that an ultrasound image that shows the anatomical structures annotated with names should be available. Another participant suggested that there should be links to more information, such as relevant pathological conditions that make the images more challenging. Finally, one participant suggested two new game modes. A game mode that plays a video and asks the user to annotate the video when it is paused, and a game mode that involves positioning the anesthetizing needle.

Other

The tasks should show a picture of the positioning of the probe, as it is important to relate the images to the probe's position. Additionally, having the same image appear several times in one game should be avoided. ALso there should be a larger image and video library with images from different patients and positions.

Finally, when identifying the structures fascia iliaca and fascia lata, the answer will sometimes be incorrect even though parts of the marker covers the structure. Perhaps the marker should be more similar to the area that is computed by the program.

5.3 Skill development

The contribution made by the five participants when they took the proficiency test is shown below. The figures show the result from the test done before using the application and then after using the application. The average time spent using the application between the first and second test was 15 minutes and the participants used it approximately two times each. Figure 5.1 shows the ultrasound image used in the test. The image is shown as it was displayed to the test personnel, and with the correctly annotated solution. When the proficiency results were briefly evaluated by the collaborating anesthesiologist on the project, he concluded that there is a clear improvement in 2 out of 5 participants, namely participant 1 and participant 3.

In figure 5.1, and all subsequent figures in this section, the labels are as follows:

Red femoral artery

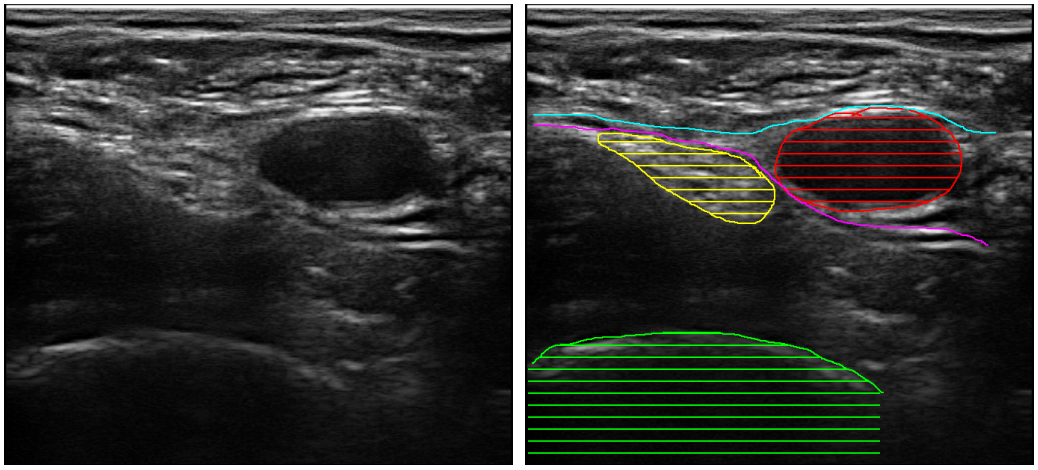
Cyan fascia lata

Green femur

Yellow femoral nerve

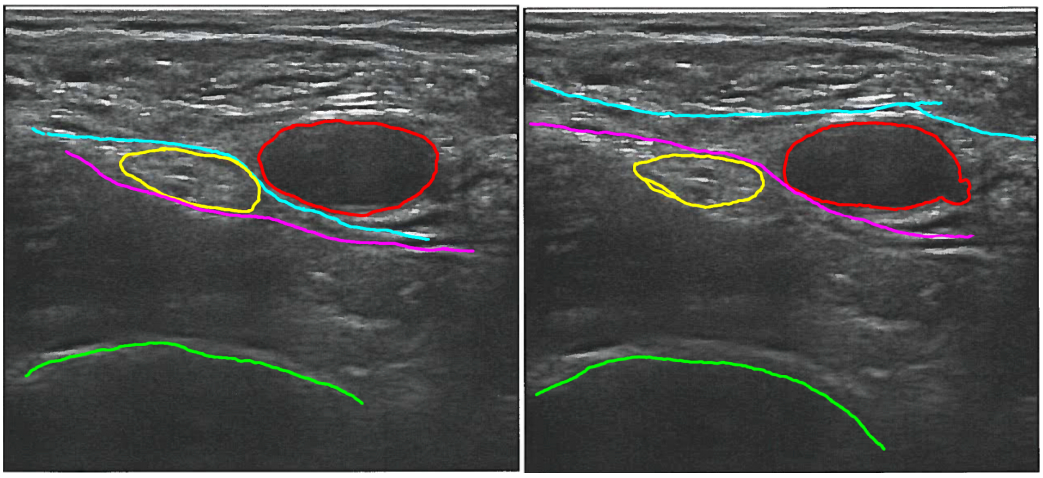
Magenta fascia iliaca

Every figure showing the first and second tests has a table summarizing the results from the tests. The summaries were written based on comparing every image to the solution, and was performed by the authors, not a medical professional. Since the participants annotated the femur and femoral artery correctly in every test, they have been left out of the summaries. The tables in question are tables 5.3, 5.4, 5.5, 5.6 and 5.7.



(a) The image as seen by testers (b) The solution to the test

Figure 5.1: The ultrasound image used in the test

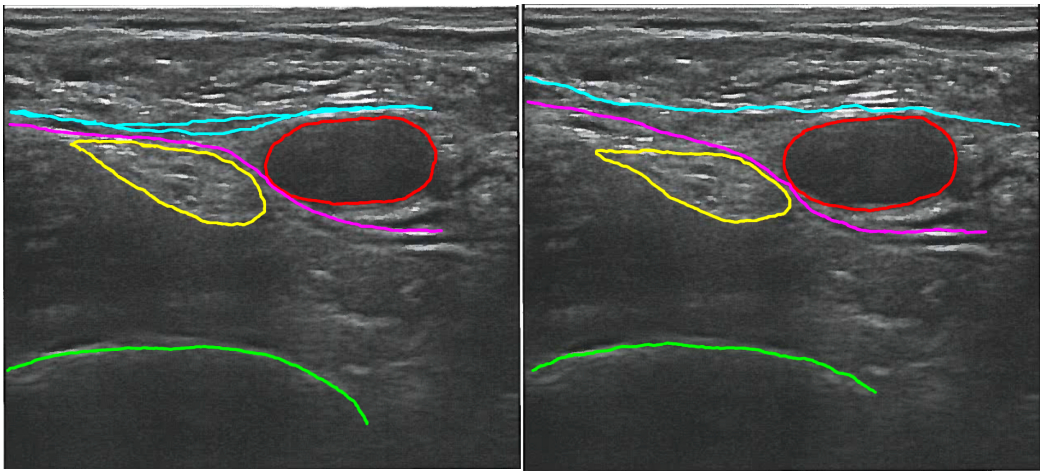


(a) First test (b) Second test

Figure 5.2: Proficiency Test: Participant 1

Structure	5.2a	5.2b
Fascia iliaca	Placed below the nerve	Correct
Fascia lata	Placed too low. Is perfectly covering the fascia iliaca instead	Positioned a little too high
Femoral nerve	Placed inside the correct area but not covering the “tail” of the nerve	Placed inside the correct area but not covering the “head” or the “tail” of the nerve

Table 5.3: Proficiency of participant 1

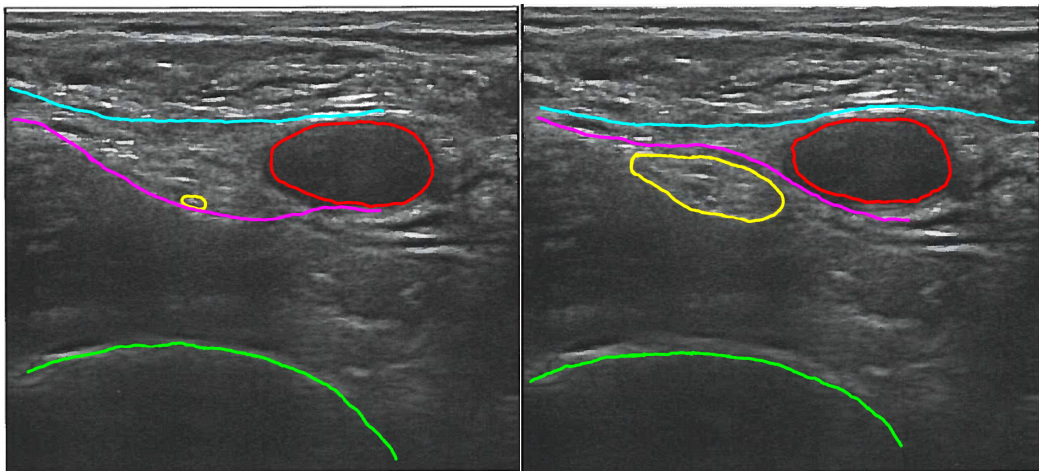


(a) First test (b) Second test

Figure 5.3: Proficiency Test: Participant 2

Structure	5.3a	5.3b
Fascia iliaca	Correct	Right half is correct, the left half is a little too high
Fascia lata	Correct	Right half is correct, the left half is a little too high
Femoral nerve	Correct	Correct

Table 5.4: Proficiency of participant 2

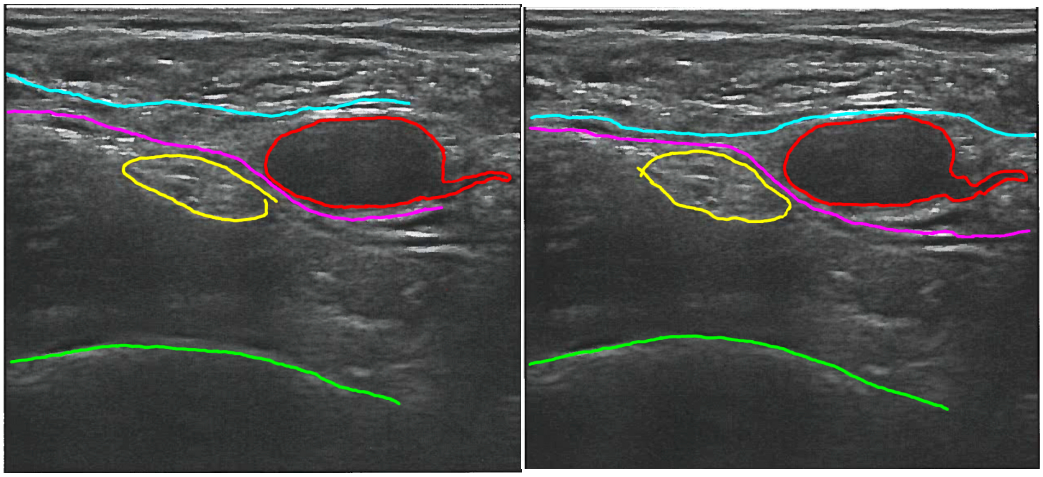


(a) First test (b) Second test

Figure 5.4: Proficiency Test: Participant 3

Structure	5.4a	5.4b
Fascia iliaca	Placed Below the nerve	Correct
Fascia lata	Right half is correct, the left half is a little too high	Correct
Femoral nerve	Correctly placed but very small	Correct

Table 5.5: Proficiency of participant 3

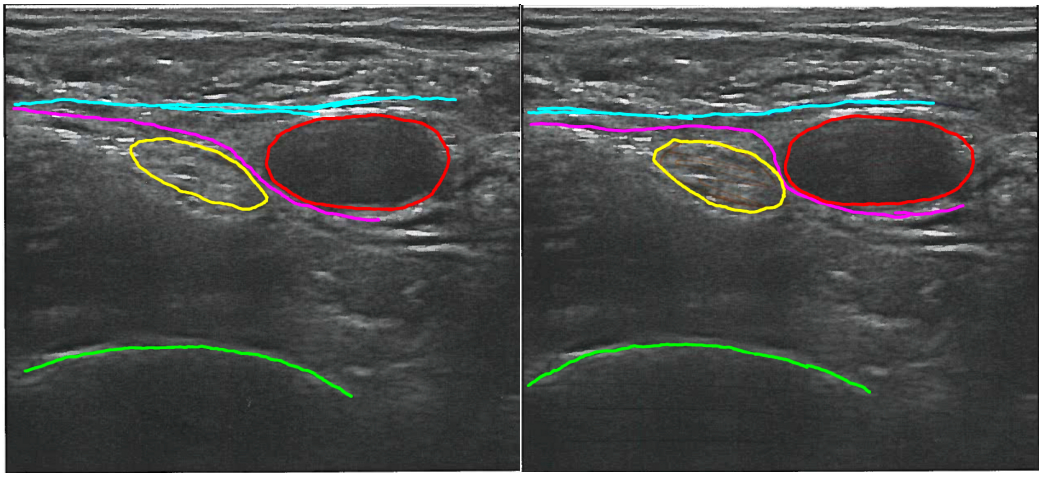


(a) First test (b) Second test

Figure 5.5: Proficiency Test: Participant 4

Structure	5.5a	5.5b
Fascia iliaca	Correctly placed in the middle, but a little too high on the left and the right	Correct
Fascia lata	Placed too high	Correct
Femoral nerve	Correct, but tail is partially left out	Correct, but tail is partially left out

Table 5.6: Proficiency of participant 4



(a) First test (b) Second test

Figure 5.6: Proficiency Test: Participant 5

Structure	5.6a	5.6b
Fascia iliaca	Correct in the middle, but too high everywhere else	Starts correctly on the left, too high in the middle, correct between the nerve and the artery, too high too the right
Fascia lata	Placed too high	Starts correctly on the left, the rest is too high
Femoral nerve	Correctly placed, but not covering everything, partially outside the nerve	Correctly placed, but not covering everything, partially outside the nerve

Table 5.7: Proficiency of participant 5

5.4 Utility as a teaching tool

To evaluate the teaching potential of the application from the point of view of a medical professional, the application was evaluated by an attending anesthesiologist at St. Olav's Hospital in Trondheim, Norway. In addition to trying the application himself he also asked his students to participate. These students are the main target audience of the application. The following section is the

feedback received from their evaluations when the application was tried on an Android device.

When asked about general impression of the application the anesthesiologist was impressed by the range of topics covered. The fact that there are several different tasks to perform enables students to get effective feedback on their abilities. A student thought the application was very well executed and useful. They thought the application was user friendly and no software bugs were encountered. In addition to no bugs, the anesthesiologist could not find any medical errors in the tasks, though he did not test it with that in mind.

When asked about aspects of the application that could have been better, the response mentioned that there was relatively much focus on the fascias, two structures that are not deemed very important from the clinical aspect. Instead, more focus should be put into recognizing nerves, arteries, muscles and bones. The feedback also stated that the way points were awarded in the game modes seemed strange.

The anesthesiologist stated that the biggest flaw in the application was the narrow field it applied to, and the fact that there was too little game content. Currently the game only contains ultrasound images from three different people. If the application also contained training material for other nerve blocks, the application would be a “superb teaching tool”. He mentioned that there were around ten nerve block procedures that would be very relevant material for the application.

Then, more specific questions about the potential for the application to be used as a teaching tool was asked. Provided more nerve blocks were added as content, the anesthesiologist said that he would recommend that students used the application before attending formal teaching situations, and that he would recommend students use it afterwards to practice. He also mentioned that he would recommend the application to other colleagues, either to revise their own knowledge, or to use when teaching their own students.

Finally, he was asked if there were any features missing from the application that could make it a better teaching tool. The anesthesiologist mentioned that another game mode concerning the positioning of the anesthetizing needle could be a good addition to the game, enabling the user to practice the next step when performing an ultrasound-guided nerve block. When asked about small changes to the application he suggested adding more “fancy” feedback in the form of color and sound effects. Though this could be seen as too unserious depending on the target group, he proposes that that the students would enjoy it.

The anesthesiologist did imply that he was excited about the potential, and indicated that he would like to further collaborate towards a better application.

Chapter 6

Discussion

This is a discussion of the results, as described in section 5, in relation to the research questions.

The results presented in chapter 5 provides the basis when answering the research questions. There are however some limitations to the user test, which may have affected the results. These limitations need to be taken into account when assessing the results.

The participants of the user test were not a part of the target audience. They did have some previous knowledge of femoral ultrasound images, but do not have the same foundation to answer some of the questions regarding use, as the actual target group.

The application was tested solely on tablets, but is also available on smartphones. When the participants were asked if they would play the game in their spare time, it may have influenced their answer. It is assumed that smartphones are easier to take out casually, whereas tablets are usually not as easily accessible.

A quantitative test should have at least 20 participants in order to be statistically significant [12]. The user test in this project consisted of 15 participants.

A presentation was held for the participants before the user test was conducted. Those present saw how the menu in the application works and briefly saw how the different game modes are played. This may have made the application easier to use than if they had no previous experience.

The participants performed the user test four at a time, due to time constraints. This did however seem to have a positive effect on the user test. The partici-

pants did not feel rushed, no one was waiting for them to finish. They could take the time they needed, and some spent a significantly more time than others.

The design of the usefulness questionnaire resembled *Likert* items, except that it lacked balanced keying, i.e. an equal number of positive and negative statements. All the statements in the usefulness questionnaire were positive, which may cause acquiescence bias [7].

6.1 RQ1:Is the educational application able to effectively teach ultrasound-guided regional anesthesia using routinely collected data?

Of all the results from the last chapter, three categories in particular will be used to evaluate the teaching potential of the application. Firstly, a group of 15 people tested the application and was asked about their own perceived learning. Secondly, 5 people took a proficiency test before and after they used the application, to evaluate if they had, in fact, learned something. And finally, the application was evaluated by an attending physician at a teaching hospital. He is the teacher of the target audience, and a person who might potentially include the application in his curriculum.

Perceived learning

As table 5.2 in the previous chapter shows, the participants were very positive when asked if they thought using the application had learning potential.

In statements 1 through 5 of the table, the participants answer if they think they learned something, if they think they would benefit from using the application regularly and if they would recommend it to a friend. They are also asked if they think it would be advantageous to use it before lectures and to revise learning material. Though one participant rated some of the statements “neutral” the rest either picked “agree” or “strongly agree”.

The test results are a promising indication that the application can be a valuable tool for teaching

Proficiency test

In order to evaluate the results from the proficiency test, a grading method was developed. The three structures fascia iliaca, fascia lata and femoral nerve were each graded on a scale from 1 to 5 in every image. The grading was based on comparing every image to the solution, and was performed by the authors, not a medical professional. The results from the grading can be seen in table 6.1

Figure		Fascia iliaca	Fascia lata	Femoral nerve	Sum	Total
5.2	a	0	0	4	4	+7
	b	5	3	3	11	
5.3	a	5	5	5	15	-3
	b	4	3	5	12	
5.4	a	0	3	1	4	+12
	b	5	5	5	15	
5.4	a	4	3	4	11	+3
	b	5	5	4	14	
5.4	a	3	3	3	9	+1
	b	3	4	3	10	

Table 6.1: Proficiency tests compared and graded

The total in the table is calculated by subtracting the first score from the second score for every image. Positive values indicate that the participant has improved, and a negative score indicates that the participant has regressed. All, except one, of the participants has a positive score, indicating that some learning has been taking place.

The consulting anesthesiologist mentioned, in the previous chapter, that he saw clear improvements in the proficiency of 2 out of 5 participants. His evaluation was done briefly, but holds greater value than interpretations made by the authors themselves. His evaluation does concur with the grading done above, as participant 1 and 3 has a significantly higher score than the rest.

Since there were only five participants, the results are not conclusive. The authors do, however, feel that the test shows a good indication of learning.

Teacher feedback

The feedback from the attending physician from section 5.4 was overwhelmingly positive.

The anesthesiologist saw a great deal of potential in the application. Although the application had a limited scope, only focusing on one nerve block, he felt that the application was very well implemented for that task. The student of the anesthesiologist who gave feedback on the application described it as useful. This student is a part of the main target audience which bodes well for the application.

The anesthesiologist did mention that there was too much focus on some of the less important anatomical structures. Particularly in the Annotation mode, where the user attempts to annotate two fascias. He expressed that it is a very good game mode, but that it would be better if it focused on the femoral nerve. This feedback shows that the game modes are useful but that some medical guidance is necessary to unlock the full educational potential of the application. However, the application showed enough potential in its current state to recruit the anesthesiologist to further collaborate on the application.

Finally, the consensus of the medical professionals was that the application would greatly benefit from increasing its field of application. If more nerve blocks were added the anesthesiologist stated that the application would be "a superb teaching tool".

As a professional in the field, and a teacher on the subject the attending physician is especially equipped to evaluate teaching methods. His endorsement is a strong indication that this application has potential as a teaching tool. It also indicates that there is a market for such an application.

6.2 RQ2: Is the educational application able to motivate medical professionals to actually use it?

In addition to the goal of making the application educational, two means of motivation was proposed as answers to RQ2. Making the application user friendly and making it fun.

The design and implementation of the user interface was made with focus on usability, and the usability of the application was evaluated using the System Usability Scale. The application scored 85.25 points out of 100, corresponding to the rating "Excellent". This score lies significantly above the average score of 68, suggesting that the usability of the application is adequate. However, some factors need to be taken into consideration. Firstly, the number of test participants was limited, and this may affect the reliability of the SUS score.

Secondly, many of the test participants were given a brief tour of the application before the test, possibly affecting how easy the application was to use.

Lastly, the participants did not fall within the target audience, which may affect their answer to the first SUS statement. The statement in question asks participants about their willingness to use the application frequently. This statement is where the application scored the lowest on usability. Since the application is not very relevant to the participants, they have little motivation to use it frequently. It may have been better if the participants were asked to answer as if they belonged to the target audience.

It is not possible to tell how much the limitations of the user test affected the overall score of the application, but as the application scored above average, by a relatively large margin, the limitations do not impact the results significantly. Feedback from the usefulness questionnaire suggests that the application still has room for improvement, but none of the participants experienced serious difficulties using the application.

Three characteristics that makes an educational game fun was described in section 2.2. Points and time restriction was added so the player could compete against themselves. For the target audience it is also assumed that they have intrinsic and cognitive curiosity towards ultrasound images, making it fun to satisfy that curiosity. The last characteristic, fantasy, was not implemented though, as it is the hardest element to incorporate. The authors do, however, feel that it could be a very good addition to the application. Fantasy goals, where the player has to perform well, or the patient experiences pain, could increase the stakes, and thereby the fun of the game. It is important to take the target audience into consideration before adding any flamboyant features such as this. Some professionals might be dissuaded from using the application if it is not serious enough.

In the usefulness questionnaire the participants were asked three questions regarding their willingness to use the application. Nearly half of the participants strongly agreed, and one third agreed, to wanting to use the application before lectures in femoral ultrasound interpretation. No participants disagreed. More than half the participants strongly agreed, and 26 % agreed to wanting to use the application to learn the material better, only 6 % disagreed. The participants were less enthusiastic about using the application when they have extra time on hand. Approximately half of the participants were neutral, and a few more participants disagreed than agreed. As mentioned earlier, the participants were not in the target group, and do not have an actual need to learn ultrasound image interpretation in their professions. This may have affected their answers regarding willingness to use application. Despite this, the partic-

ipants were overall very positive

The results indicate that the users found the application to be user friendly and fun. They had a strong willingness to use the application and this is important as willingness to use the application leads to more learning. The project concludes that the application is able to motivate medical professionals to use it.

Chapter 7

Future Work

7.1 Game modes

This section proposes changes and new features that may be incorporated into the game. The additions may turn the game into a better teaching tool, either by improving the game experience, or by adding new theory. The suggestions are based on the feedback from section 5.2.2 and 5.4.

7.1.1 Game mode improvements

The Annotation game mode only asks the player to annotate the fascia iliaca and the fascia lata. According to the feedback from section 5.4, other, important structures should also be added to the game mode. The femoral nerve, in particular, should be included, as it is the main target of a femoral nerve block. The femoral nerve was not included due to time constraints, as it requires a more complex implementation than the simple curves used for the fascias.

The Point-and-Click game mode should give the player feedback on their progression through the game. The progression may be displayed through a progress bar, or through text.

7.1.2 New game modes

A game mode designed to teach needle positioning was mentioned twice in the feedback from the user tests. One of the recommendations was made by the

anesthesiologist. The game mode would simulate needle placement during a femoral nerve block, giving the player feedback on ideal needle placement. This introduces the player to more theory from the femoral nerve block procedure, than simply ultrasound image interpretation.

7.2 More areas of regional anesthesia

The femoral nerve block is only a small part of regional anestesia. There are several different nerve block procedures performed very similarly to the FNB, for example infraclavicular nerve block (the elbow and below) and sciatic nerve block (the thigh and lower leg). If these procedure are added to the application, it would add significant value for the target audience

Adding more nerve blocks to the application is not very difficult, as the game modes may be reused. Only the image content and task questions need to be replaced.

7.3 Server communication

If a server back-end is developed, several additional features may be implemented.

7.3.1 Login and global high score

A login implementation could provide the application with user profiles. User high scores could be saved, and a high score list generated. With a high score list, friends and strangers may compete to score higher than each other, either through global or local high scores.

Adding a competitive feature might make the application more entertaining and thus motivate players to perform.

7.3.2 Downloads

As described in section 4.3.3, a Downloads page was planned for the application. The Downloads page would let users download additional content to the

games, such as ultrasound images and videos. Having images and videos originating from different people is important, as the anatomical structures may vary from person to person.

New data could be downloaded, from a server, in packages, with the easy option of deleting packages to save storage space on devices. In order to update the server with new content, a server application with a GUI should be implemented. This allows non-programmers to add content, which should increase the maintainability and longevity of the application.

Chapter 8

Conclusion

Data that is routinely collected from procedures may be made available through an educational application. There is potential for students to learn faster on their own if such data is made available to everyone with a smart device. To investigate the potential of such an application the project was based around the following two research questions.

RQ1 Is the educational application able to effectively teach ultrasound-guided regional anesthesia using routinely collected data?

RQ2 Is the educational application able to motivate medical professionals to actually use it?

To answer the research questions a prototype was developed. It focused on incorporating ultrasound images in a fun and accessible way while still being educational. The prototype was then evaluated through a small user test designed to test usability, entertainment and educational value.

There were some flaws in the testing. Mainly that there were too few participants to create a statistically significant conclusion, and that the participants did not actually belong to the target audience.

RQ1
Three methods of evaluation were used to answer RQ1, and all indicated that the application did in fact have educational value. The first method evaluated the participants perceived learning. The second method compared practical annotation tests the participants performed. The third method asked a teacher in the field to evaluate the application and give feedback. The teacher indicated that with more content the application would be a “superb teaching tool”.

RQ2

The evaluation of RQ2 consisted mainly of questionnaires that the participants filled out. The answers indicated that the participants found the application easy to use, and that they were willing to use it. They were willing to use the application despite the fact that it is not very relevant to their own professions.

Most participants answered that they did in fact get “carried away” while playing the game, and a few indicated that the time restriction was the reason for this.

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Appendices

Appendix A

SUS Survey

System Usability Scale

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

* cumbersome = tungvint

** does not include confidence in your knowledge of ultrasound images

Appendix B

Usefulness questionnaire

Femoral Nerve Block App

1. **What is your medical background?**
   Mark only one oval.

   - ◯ Medical student
   - ◯ Medical doctor
   - ◯ Other: .....

2. **Are you familiar with femoral ultrasound images?**
   Mark only one oval.

   - ◯ I use it in my profession
   - ◯ I am going to learn to use it in my profession
   - ◯ I do not use it in my profession
   - ◯ Other: .....

Learning Outcome

1 - Strongly disagree
2 - Disagree
3 - Neither agree nor disagree
4 - Agree
5 - Strongly agree

3. **I think the app made me learn how to interpret ultrasound images**
   Mark only one oval.

   - ◯ 1
   - ◯ 2
   - ◯ 3
   - ◯ 4
   - ◯ 5

4. **I think it is an advantage to use the app before relevant lectures in ultrasound interpretation**
   Mark only one oval.

   - ◯ 1
   - ◯ 2
   - ◯ 3
   - ◯ 4
   - ◯ 5

5. **I think regularly using the app can help me learn the material**
   Mark only one oval.

   - 1
   - 2
   - 3
   - 4
   - 5

6. **I think it is wise to use the app to revise the learning material**
   Mark only one oval.

   - 1
   - 2
   - 3
   - 4
   - 5

7. **I would recommend this app to a friend**
   For example if you are discussing femoral untrasound
   Mark only one oval.

   - 1
   - 2
   - 3
   - 4
   - 5

Range of use

1 - Strongly disagree
2 - Disagree
3 - Neither agree nor disagree
4 - Agree
5 - Strongly agree

8. **I would use the app before I have lectures in femoral ultrasound interpretation**
   Mark only one oval.

   - 1
   - 2
   - 3
   - 4
   - 5

9. **I would use the app to learn the material better**
   Mark only one oval.

   - ◯ 1
   - ◯ 2
   - ◯ 3
   - ◯ 4
   - ◯ 5

10. **I would use the app when i have extra time on hand**
    For example on the bus or while I wait for a doctors appointment
    Mark only one oval.

    - ◯ 1
    - ◯ 2
    - ◯ 3
    - ◯ 4
    - ◯ 5

The App

11. **Which game modes did you prefer? (Why?)**
    Point and click, Annotation, Video

    .....

    .....

    .....

    .....

    .....

12. **Which game mode did you like the least? (Why?)**

    .....

    .....

    .....

    .....

    .....

13. **Is there something you think could improve the app?**

    .....

    .....

    .....

    .....

    .....

14. **Is there some functionality you feel were missing from the app?**

15. **Were the game functions fun enough so that you felt “carried away”?**

Appendix C

Results from usefulness test

	1 Medisinsk bakgrunn	2 Kjennskap til femorale ultralydbilder	3 Lærte å tolke ultralydbilder	4 Fordel å bruke app før forelesning	5 Jevnlig bruk - lære materialet	6 Bruke til repetisjon	7 Anbefale til en venn	8 Brukt appen før forelesning	9 Bruke for å lære materialet bedre	10 Bruke ved tid til overs
1	Other: Ingen (Biofysikk)	Other: Prosjekt, kommunikasjon med leger	4	4	4	4	4	4	3	3
2	Other: Forsker SINTEF	Jeg trenger det ikke i yrket mitt	5	5	5	5	5	4	5	4
3	Other: Ingeniør	Jeg trenger det i yrket mitt	4	5	5	5	5	5	5	3
4	Other:	Other: Har sett litt av dette (video)	3	4	4	4	5	5	5	2
5	Other: Ingen	Jeg trenger det ikke i yrket mitt	5	5	5	5	5	5	5	3
6	Other: Forsker MedTek	Jeg trenger det ikke i yrket mitt	4	5	4	5	5	5	2	2
7	Other: Forsker - Tekn	Other: Avhengig av prosjekt	5	5	5	5	4	5	5	3
8	Other: Ingeniør	Jeg trenger det ikke i yrket mitt	4	5	5	4	4	5	5	3
9	Other: Teknolog	Jeg skal lære å bruke det i yrket mitt	4	4	4	4	4	4	4	4
10	Other: Ikkemedisinsk	Other: Nei	4	4	4	5	5	5	5	1
11	Other: Teknolog, med.tekn.	Jeg trenger det i yrket mitt	4	4	4	4	5	4	4	2
12	Other: Ikkemedisinsk	Jeg trenger det ikke i yrket mitt	5	5	5	5	5	3	5	3
13	Other: Research Scientist	Jeg trenger det ikke i yrket mitt	4	4	3	4	3	3	4	3
14	Other: Engineer	Jeg trenger det ikke i yrket mitt	4	5	4	4	4	4	4	3
15	Other: No medical background, engineer	Jeg trenger det ikke i yrket mitt	4	3	4	5	5	3	5	4

11 Beste spilltype	12 Dårligste spilltype	13 Forbedring
Pek og klikk: aktivitet, aktiv læring	Video: nødvendig, men passiv læring	Flere ulike eksempler
Pek og klikk: mer krevende og gir kanskje mer læringsutbytte	Annotering: kanskje, føltes mindre lik virkeligheten	Flere bilder / videoer
Annotering	Video: mangler forklaring	Annotering av flere strukturer. Score basert på avstand.
Video: Mer praktisk setting. Annotering: Bedre enn bare å klikke på et punkt.	Expert: Fordi den ikke pauser når fasit viser.	Pause ved fasit i expert. Easy kunne hett "Practice" uten poeng
Pek og klikk: Expert	Easy: For enkelt	Progressindikator i gamemodes f.eks. 5/10 eller 10%. Spesielt i expert mode: Det var "plagsomt" å måtte trykke confirm, jeg mistet tid.
Annotering: Alle 3 var bra, men annotation var best pga mer interaksjon.	-	Noen ganger dukket samme objekt opp flere ganger. Unngå dette.
Pek og klikk: Må ta en selvstendig avgjørelse og rask tilbakemelding	Expert: Krevde litt for mange unødvendige knappetrykk	Expert modus krevde for mange unødvendige knappetrykk
Pek og klikk: Fordi det gav fasit etterpå	Video	-
Pek og klikk	-	Expert: Pause tiden når området er valgt
Video m/ tid	Vet ikke	Vet ikke
Synes alle var bra, god progresjon i oppgavene	-	Måle avstand fra målet og gi poeng utfra det, ikke bare wrong/correct? Kan gjelde for fascia ihvertfall...
Både Pek og klikk med ulike nivå og annotation. Fin progresjon i læringen.	Video: Litt vanskelig å skjønne bruksområde, men dette forstår kanskje klinikere.	Startmenyen. Tydeliggjøring av oppbygningen - at det er 3 ulike spill, med økende nivå.
Pek og klikk	Annotering	-
Video: Kanksje mest relevant iom. at det å finne riktig utsnitt er svært vesentlig for å kunne identifisere de aktuelle strukturene. Pek og klikk: Hadde fin utforming mhp. easy -> expert (Selv om easy kanskje var i letteste laget. Kan med fordel kalles noe annet, f.eks. tutorial mode.)	Annotering: Kanskje, skjønte ikke hvorfor det heter det. Rundingene burde vært mulig å flytte sideveis også.	1. Navnet på "Annotation" -> "Find/Place anatomical structures"? 2. Navnet "Video" -> "Find the right imaging plane"? 3. Hva betyr "Multiplier" oppe i høyre hjørnet? 4. Særlig når man trykker på fascia iliaca og fascia lata så ble det noen ganger feil svar, selv om krysset dekket mye av streken. Kanskje markøren bør være mer like det området som faktisk velges og vurderes av programmet.
It was a natural progress. Since I do not know the field, I found going from easy to difficult was a very good thing to do. So I would keep all 3 options. Video was funk, but I needed all 3.	-	1. Showing a picture of graphics of the positioning of the probe! It is important to relate the images to the probe position. 2. Larger picture library - different patients/positions.

14 Ekstra funksjonalitet	15 Revet med
Lenke til mer info, f.eks. relevante patologiske tilstander som gjør bildene mer utfordrende	Yes
Ikke som jeg kommer på	Ja, definitivt!
-	-
Video med annotering ved stopp. Hvor vil du plassere sprøyta med bedøvelse?	Ja
Highscore	Ja, expert var gøy. Tiden gjorde det spennende
-	Tja...det var ihvertfall helt klart verdt 10 minutter.
Tilbakemelding på progresjon	Ja
Nei	Ja (overraskende nok)
Nei	Ja
Nei	Ja, litt
Nei	Ja
Et stillbilde med navnene og områdene	JA :)
-	-
Design: Tydelig deling mellom de tre ulike spillene kunne vært en fordel.	Særlig "Expert" med tidtakning var spennende
-	Video - annotate as quickly you can

Appendix D

Gemini article

Denne appen skal lære helsepersonell å tolke ultralydbilder. Appen gjør det mulig å trene hvor som helst, noe som bidrar til at man lettere kan få mengdetrening i bildetolkingen. Foto: Håvard Egge.

Lærer å forstå ultralyd med app

Det brukes stadig oftere ultralyd. Nå er det utviklet en app som skal lære opp helsepersonell til å tolke ultralydbildene.

Av Håvard Egge
Publisert 10.06.15

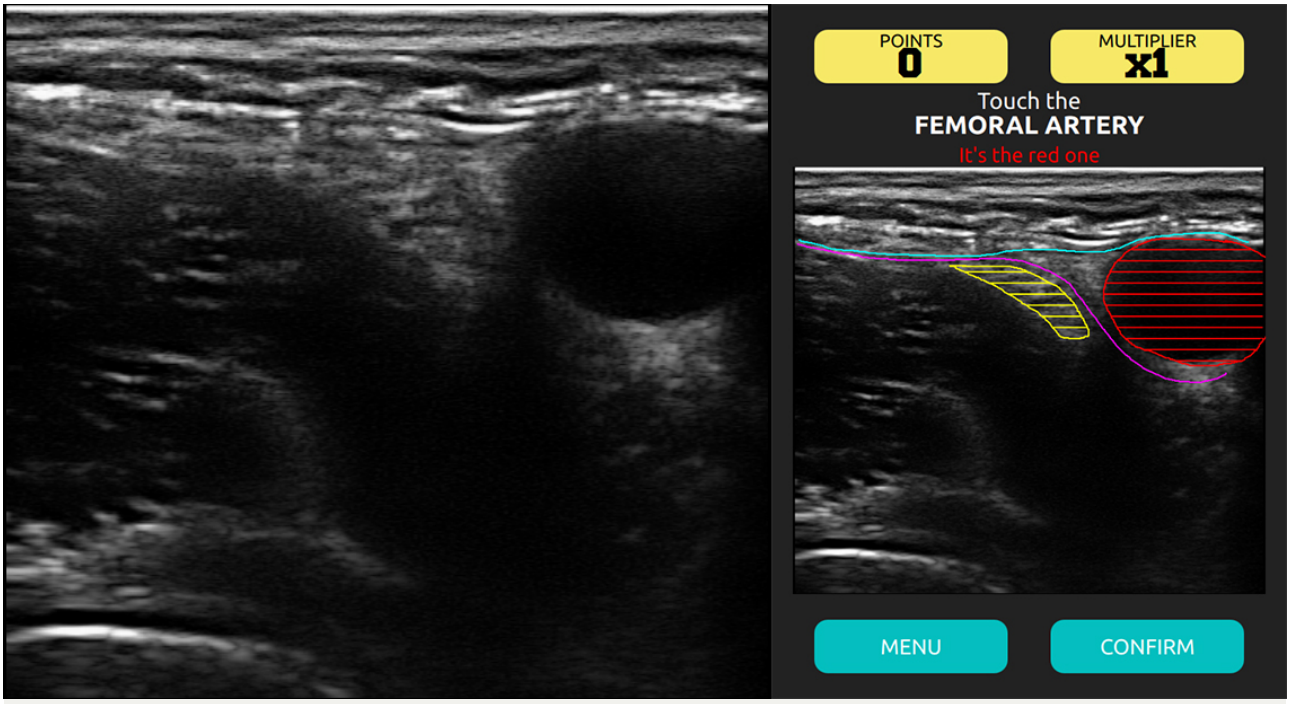
En ny app skal gi helsepersonell nødvendig trening og erfaring i å tolke ultralyd.

– Det er stadig lavere terskel for å bruke ultralyd, og flere må lære seg å tolke det de ser. Derfor er det viktig at de blir eksponert for mange forskjellige ultralydbilder, sier SINTEF-forsker Frank Lindseth.

Kan spare narkoser

De fleste forbinder ultralyd med fosterundersøkelser, hvor man som kjent kan se at utviklingen til barnet er riktig. Det mange ikke er klar over er at man i dag kan ta ultralyd av det aller meste på kroppen, og bruke det til blant annet å undersøke prostata og hjerte, samt til ulike inngrep, som for eksempel å fjerne en svulst i hodet.

– En stor fordel med ultralyd er at den gjør mange undersøkelser og inngrep enklere og mindre tidkrevende å gjennomføre, og dessuten lettere for pasienten. Ved mange tilfeller kan ultralyd for eksempel spare en pasient for full narkose, forteller anestesilege Kaj Johansen som har bidratt med data. Han synes appen er blitt nyttig og instruktiv.



I appen får brukerne presentert et ultraydbilde. Oppgaven på dette bildet er å identifisere arterien som vises i rødt på det enkleste nivået. På det vanskeligste nivået skal man gjøre det samme uten hjelp og på tid, slik at man hele tiden skal kunne forbedre seg. Her letes det etter en nerve i låret. Skjermdump av appen til høyre, ultralydbildet til venstre.

Motiverende med spill

Frank Lindseth har flere års erfaring med bruk av ultralyd. Ideen til en app har han hatt i flere år, men det har vist seg vanskelig å få midler til å realisere den. Nå har han fått hjelp av masterstudenter i datateknikk ved NTNU til å lage en betaversjon.

Appen er utformet som et spill for å gjøre det motiverende å lære, forklarer masterstudentene.

– Tilbakemeldingene vi har fått fra helsepersonell som har prøvd den har vært positiv. De var overrasket over hvor gøy det var å bruke den, forteller Hanna Holler Kamperud og Solveig Hellan.

Spillet har tre vanskelighetsgrader, slik at man kan få nye utfordringer etter hvert som man blir flinkere. På den første vanskelighetsgraden får man all hjelpen man trenger mens på det vanskeligste nivået jobber man på tid.

– På den måten kan man alltid forbedre seg, forklarer studentene.

Lærer å bedøve en fot

I appen lærer man å identifisere lårnerven som går ut til foten. Oppgaven går ut på å stikke nåler i nærheten av nerven, slik at den blokkeres og foten blir bedøvet, så man kan gjøre inngrep.

Så langt er det lagt inn et begrenset bildemateriale i appen.

– Målet er å få lagt inn et større og mer variert datamateriale med flere ultralydbilder og oppgaver. Når vi får gjort det blir det naturlig å legge ut appen til nedlastning, forteller Lindseth.

Fordelen med å bruke en app til opplæring er at den er tilgjengelig hele tiden.

– Det er viktig at den blir brukt mye for den eneste måten å bli god på å tolke ultralydbilder er å få det inn i blodet. Tanken er at man skal kunne ta den frem på bussen, på venteværelse eller hjemme i sofakroken, forklarer Lindseth.

Planen er at appen skal legges ut på Google Play (Android) og App Store (iOS) – og bli tilgjengelig for alle, så fort man får lagt inn litt mere datamateriale opplyser SINTEF-forskeren.