CHALMERS
UNIVERSITY OF TECHNOLOGY

UNIVERSITY OF GOTHENBURG

# Accessible Card Presentation in Board Games

## Developing an Application for Individuals with Visual Impairment

Bachelor's thesis in Computer science and engineering


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# Abstract

Board games are a popular form of entertainment played in many cultures and countries in similar and different forms around the world. However, board games usually present barriers to people with visual impairments. One of these barriers is the card element in board games since these cards can be a hassle to read for individuals with visual impairment. This dissertation focuses on how cards in board games can be presented in a more accessible way through an application. Three interviews with individuals who either are visually impaired or have experience working with people with visual impairment were conducted to guide the development of the application. The application works by identifying a card with the camera of a phone or tablet. Then, the card is presented and stored in the application in a more accessible format, using higher contrasts, color-blindness-friendly colors, and a screen reader-compatible format. Cards are identified through a combination of image recognition and text recognition. One challenge throughout the report was the broad range of visual impairments, where different solutions work for different individuals.



# Sammanfattning

Brädspel är en populär form av underhållning och spelas i många kulturer och länder runt om i världen, i liknande och olika former. Brädspel innehåller dock vanligtvis hinder för personer med synnedsättning. Ett av dessa hinder är korten i brädspel, eftersom dessa kort kan vara svåra att läsa för personer med synnedsättning. Denna avhandling fokuserar på hur kort i brädspel kan presenteras på ett mer tillgängligt sätt genom en applikation. Tre intervjuer med personer som antingen är synskadade, eller har erfarenhet av att arbeta med personer med synnedsättning genomfördes för att vägleda utvecklingen av applikationen. Applikationen används genom att ett kort identifieras med kameran på en telefon eller surfplatta. Därefter presenteras och sparas kortet i applikationen i ett mer tillgängligt format, med högre kontraster, färger som fungerar för färgblinda och ett format som är kompatibelt med skärmläsare. Korten identifieras i applikationen genom en kombination av bildigenkänning och textigenkänning. En utmaning genom hela rapporten var det breda spektrumet av synnedsättningar, där olika lösningar fungerar olika bra för olika personer.



Keywords: board games, accessibility, visual impairment, accessible design, text recognition, pre-trained few-shot model, prototypical networks

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Authors, Gothenburg, June 2023

# List of Acronyms and Vocabulary

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

| | |
|---|---|
| API | Application Programming Interface |
| CNN | Convolutional Neural Network |
| CSS | Cascading Style Sheets |
| HTML | Hypertext Markup Language |
| OCR | Optical Character Recognition |
| Meeples | A combination of "my" and "people" and are little wooden person-shaped tokens that represent the player |
| MVP | Minimal Viable Product |
| NFC | Near Field Communication |
| NoSQL | Not only Structured Query Language |
| TLS | Transport Layer Security |
| UI | User Interface |
| UX | User Experience |
| Vectorize | To turn into a vector |
| WSGI | Web Server Gateway Interface |
| XML | Extensible Markup Language |

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# 1
# Introduction

*Accessible Card Presentation in Board Games: Developing an Application for Individuals with Visual Impairment* is a Bachelor's thesis in the Department of Computer Science and Engineering.

## 1.1 Background of board games

Board games have experienced a resurgence in popularity in recent years, with more people rediscovering this enjoyable and social way to spend their free time [1]. The topic of board games involves a wide range of games with different characteristics. Some have a board, as the name states, and pieces like cards, dice, and meeples. Some consider games that only consist of cards board games as well. Board games are usually multiplayer, but there are two-player games like Quarto or chess, and single-player games like Mage Knight or Spirit Island. Rule-sets and strategic depth are things that heavily differ between different games, chess for example has quite simple rule-sets but deep tactical planning. There are also competitive and cooperative tabletop games and other categories [2].

### 1.1.1 Board games as means of communication

People of all ages play board games. Grandparents and parents can play with their kids under the same rules. It could therefore create a strong emotional bond between families and friends [3]. It also helps children and less socially active adults to socialize in a fun and interactive way. Actions such as interacting with other people become secondary and a means to try and win the game, and therefore it's less likely for people to overthink them. Additionally, board games can be a good way for interacting with foreigners and learning about other countries' languages and cultures. Many of them such as chess, checkers, monopoly, and so on, are played worldwide [4].

Opportunities for social interaction are especially important for individuals with visual impairment since they encounter various social challenges in their daily lives [5]. Their inability to perceive nonverbal cues, and others' unfamiliarity with proper etiquette when interacting with visually impaired individuals, such as whether or not to extend a handshake, can result in discomfort for both parties involved. In addition, people with visual impairment overall have an increased likelihood of experiencing social isolation [6]. Therefore, enhancing social integration, for instance through the development of better assistive tools, is important for improving the

mental health of people with visual impairment. It's important to mention that the range of visual impairment is broad, for example, some people can see perfectly well with regard to what is in front of them but might have no peripheral vision [7]. More on visual impairments in section 2.1.

### 1.1.2 Challenges of board games for people with disabilities

Board games could be a means for people with visual impairment to become more socially active. However, playing board games can be more challenging for people with disabilities. Board games must be fitted and adapted to help individuals with disabilities improve their cognitive, physical, and social skills. That aside, they must be enjoyable and provide fulfillment in a world where disabled people may feel limited.

There is a trade-off between how challenging and how including board games can be. Obstacles exist in games to make them more challenging, otherwise, there would be no reason to play. On the other hand, some of these challenges are not suited for people with certain types of disabilities. Often, these challenges are also unintentional. Heron [8] states that the important part is that the accessibility issues in games are intentional, meaning they are there for a specific reason; to make the game more challenging and fun.

There are two main approaches for making board games more accessible for those with disabilities [1]. The first one is to change the design of the components and rules of the game, and the second one is through the use of assistive digital tools. Following the first approach, games can be designed with e.g. braille tactile markings as shown in figure 1.1 and audio cues on the pieces, to help players distinguish them by touch or sound. Larger text and higher contrast are also factors that benefit people with visual impairments. But from an economic perspective, it is unfavorable for board games to accommodate the wide range of disabilities. Additionally, creating such board games might make it less challenging, which affects the enjoyment of playing the game in the first place, or increase the manufacturers' costs to make e.g. larger board games and dice [9].

There are board games designed for visually impaired people but they're few. Making board games more accessible for people with visual impairment would not only help them become more socially active but also become less dependent on the visually abled to read or clarify something for them. This is especially important for the card element of board games which sometimes is to be kept secret. This challenge can potentially be dealt with through the use of assistive digital tools designed for the visually impaired, which also takes into account the social aspect of not wanting to have a visible assisting device.

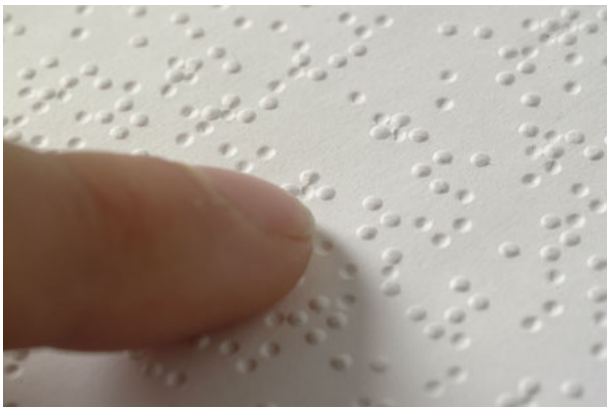


Figure 1.1: Braille code [10]

## 1.2 Motivation of this project

This project aims to examine a potential way to make cards in board games more accessible for individuals with visual impairment, through the use of an application. The application is intended to present the content of cards in board games in a way that is easier to understand for someone with visual impairment. That way, the application will compensate for difficulties caused by inaccessible card design, and aid people with more severe visual impairment where accessible card design would not have been enough. The primary goal of this project is to take one step towards making board games more inclusive for people with disabilities and thereby attracting a broader audience to the board gaming community. The focus of this report is on visual impairment since the authors have experience in programming, and digital technology has the potential of working well as an assistive tool for individuals with visual impairment when playing board games [11].

## 1.3 Problem formulation

The research aim of this report is to plot a way of creating an application that makes cards in board games more accessible for people with visual impairment.

However, developing an application aimed at individuals with visual impairment comes with some challenges. The application is intended to work as a tool, and should therefore be easy to use. With this specific audience, it is of great importance that the application is easy to navigate and is designed in a user-friendly format. For example, the content of the cards needs to be presented in a way that is easy to read. Since the range of visual impairment is broad, the application should be tailored to be useful for the wide spectrum of different visual impairments. This can be difficult since the range of visual impairment is vast, and the application needs to take into account both endpoints of the spectrum.

Additionally, the content of the application has to be decided. This involves considering features and functionalities that would be valuable in an assistive device

designed to make card reading more accessible. A decision then has to be made on which of these features to actually include in the application.

Furthermore, the aim is for the application to be a natural part of playing board games. It is therefore important that the application does not distract the actual gameplay too much. The problem identified here is that the application both needs to be accurate when identifying cards, but also fast enough not to slow down the gameplay to an extent. Therefore, different ways to identify cards should be examined, and an evaluation on which one to use has to be made.

This results in the following research questions:

### Research questions

- How could the application be designed to make it user-friendly for individuals with visual impairment?
- What are some important features and functionalities to include in the application?
- What are some potentially useful ways to digitally identify cards in board games?

## 1.4 Scope

The subject of visual impairment is broad and there is a wide range of conditions with different symptoms and levels of severity. A solution that works for every individual with visual impairment will therefore not be possible to cover or aim for.

The language of the project is limited by the project group's proficiency and the target audience is English-speaking players.

The solutions that were thought to move the player too far from the authentic board game experience were rejected.

To be able to evaluate the project, tests on the final product will be performed. Due to time limitations, these tests will only be performed by the group and focus on how the product improves gameplay and whether or not it disrupts the game flow, as well as how accurate the card identification is.

The application is considered done when it works as described earlier for the game Catan but has the capability to operate on other board games as well if they were to be added.

## 1.5 Target group

The main target group for this project is people with visual impairments. The reason for the choice of this target group is that digital tools for the visually impaired, specifically tools designed for smartphones, is a research area that is on the rise [12]. According to Senjam [12], 95% of visually impaired people find apps designed to be accessible, useful, and improve their day-to-day life. The secondary group of stakeholders consists of caregivers, family members, and friends who play with people with visual impairments. Thirdly comes teachers and professionals as well as organizations and institutions that support vision-impaired individuals. Lastly are board game designers and manufacturers who are interested in the market of board games for people with sensory difficulties.

However, the target group for this project may be even broader. This could be a case of universal design, known as the curb cut effect, where something specifically designed to aid disabled people also ends up being beneficial to many more [13]. After all, ordinary people in extraordinary circumstances have the same kind of issues as extraordinary people in ordinary circumstances [14]. Paying attention to features that would facilitate playing board games for people with vision difficulties would be help directed to everyone, mainly since our vision worsens as we grow older and partly because the support could benefit some of the other categories of disabilities as well.

## 1.6 Related work

Adapted and special needs board games do exist for individual games such as Braille version of Monopoly and accessible chess sets.

Heron, Belford, Reid, *et al.* [15] aims to explore the accessibility of modern board games and discusses the accessibility issues that designers can learn from and consider in their work. Heron, Belford, Reid, *et al.* [16] focus on navigation, mainly through screen readers, text-based maps, and memory. It highlights the importance of avoiding only visual-based games and including blind players when designing games or working on projects that revolve around visual disabilities.

Searching with the terms ("All Metadata":board games) AND ("All Metadata":sight-impaired people) OR ("All Metadata":visually-impaired people) in IEEE Xplore resulted in relevant articles. In the research "A Multimodal Interface Device for Online Board Games Designed for Sight-Impaired People", hardware using both braille writing system and tactile switches enables sight-impaired people to play online board games [17]. Another paper in ACM Digital Library presents a workspace called Game Changer, which has audio guidance and tactile landmarks to help blind and visually-impaired people easily play board games [18].

These studies have in common prototypes that either consist of additional phys-

ical landmarks that can be attached to board and card games, or devices that can be used separately to make the experience more accessible. The research gap that this project aims to fill lies in creating an assistive application that can be used on portable daily-usable devices such as smartphones and tablets.

## 1.7 Ethics

The digital tool that will be developed in this project has the potential to do a lot of good for society. From a consequential ethical perspective, a possible outcome of this project is that people with visual impairments feel more included in the board game community, and possibly also in society as a whole. It could also draw light on the exclusion of people with visual impairment within the board gaming area [1], hopefully leading to more inclusion in the future.

Since the application is developed by people without visual impairments for people with visual impairments, with the goal of making board game playing easier for them, it is important for the developers to avoid making decisions according to their own assumptions about the design and features of the application. From a virtue ethical aspect, it could be perceived as disrespectful if the application was designed more according to the group's desires than to benefit visually impaired people. Therefore, it is important to consequently communicate with experienced people on the subject and to do adequate research.

Another important aspect is the duty ethical perspective, how data from users are to be handled in the application, especially as it might require access to input from a camera or a microphone. Throughout the development, care needs to be made to make sure no personal information is saved and the integrity of the user is protected. Besides the case where a user by choice may be able to contribute to improving the application or communicate game states to other players, data should not be saved outside the user's device nor shared with third parties.

Though the aim of the project is to lessen the impact of unintentional disadvantages for a subset of people, a potential side effect could be that the tool itself creates an unfair advantage. One example of this could be when a function in the application is used to cheat. An action that might be allowed in one game can in another give access to information not meant for the player to be able to receive, such as previous game states or recent discards. Whether this is allowed or not is up to the game rules and something the application likely won't take into consideration. While cheating is possible without the tool, it might be more difficult for other players to detect if done through an app. Even so, the consequences of this risk seem negligible compared to the benefits but are worth having in mind while designing the application and its functions.

Another concern about the project is that it could increase the already existing digital exclusion that some people with visual impairments experience [19]. Not everyone has been able to keep pace with the rapid digitalization that is ongoing

in society. For visually impaired individuals, the impact of digitalization is much greater as most of the assistive devices they rely on are digital. The tool that is created in this project is not an exception. Therefore, it is essential that the application is as easy to use as possible, to ensure that it is accessible to as many people as it possibly can.

# 2
# Theory

This chapter presents the theoretical background of the project. This consists of an explanation of what visual impairment is, and the necessary theory for the card identification process.

## 2.1 Visual impairments

The definition of visual impairment is not always straightforward, as it has evolved over time and may vary between countries [20]. The International Classification of Diseases 11 (ICD-11) establishes a universal definition of visual impairment, which has been adopted by the World Health Organization and is also used in this report [21]. The definition states that a person is considered visually impaired if their visual acuity is 0.3 or worse in the better eye with full correction or if they have a near vision acuity of N6 or worse and blind if their visual acuity is 1.3 or worse. Other visual functions, such as contrast sensitivity, color blindness, and field of vision are also mentioned in the definition.

Contrast sensitivity refers to the ability to distinguish between different levels of brightness [20]. It is common for people with low vision to have difficulties differentiating objects with low contrast. Individuals with low contrast sensitivity could potentially benefit from applications that present text using higher contrast.

There are three types of color blindness, with the most prevalent type being red-green, which causes difficulty distinguishing between red and green hues [22]. The other types of color blindness are yellow-blue color blindness and total color blindness. Yellow-blue color blindness means having difficulty distinguishing between different colors that lie between yellow and blue on the color spectrum. For individuals with color blindness, taking content written in color-blindness-unfriendly colors and displaying it using more suitable color combinations may be helpful.

The field of vision is the entire area a person can see when looking at a specific point [20]. Neurological conditions can cause defects to appear in the field of vision, making it harder to search for objects or details. For individuals with this condition, it may be helpful to have the possibility of having information read out loud.

As previously mentioned, the category of visual impairment encompasses a wide range of conditions. As such, the needs and experiences of individuals with visual

impairments can vary significantly from case to case. Common causes of visual impairments include [23]:

**Age-related macular degeneration (AMD)** can affect visual acuity through the appearance of small spots in the middle of the field of vision or through the vision turning gray and blurry. Individuals with AMD may encounter difficulty reading, as the condition also can cause letters or parts of words to vanish from their field of vision. Someone with **cataracts** may instead experience foggy and blurry vision with a weaker perception of colors. For individuals with **diabetic retinopathy**, black spots may appear in their field of vision or their vision may become blurry. **Glaucoma** on the other hand can cause the field of vision to shrink and become darker.

The intention is to make the intended application in this accessible for all the mentioned types of visual impairment and color blindness.

## 2.2 Digital tools for people with visual impairment

As technology advances, the field of tools designed to aid individuals with visual impairments has undergone a significant transformation [24]. While physical tools such as handheld magnifiers and telemicroscopes were once the primary means of assistance, digital tools have since emerged as valuable resources for those with visual impairments. In today's world, there are a plethora of technologies [25] available that can significantly enhance the daily lives of individuals with visual impairments. There are e.g. screen-readers that provide a description of everything happening on the screen, voice recognition systems that through sound have access to almost every feature in the phone, applications that through machine learning are able to identify objects, glasses tools for magnifying text and other objects, voice-to-text and audiobooks for reading text and books out loud, global positioning system (GPS) for navigation and transportation, and communities for the visually impaired in social media.

A screen reader is a tool that, using text to speech or braille, allows blind or visually impaired people to use digital devices [26]. On mobile devices, touching or swiping allows the user to navigate and understand what is on the screen. On a desktop, the user instead uses their keyboard. Images, tables, and similar are described using alternative text that has to be added by the developer. Similarly, buttons, checkboxes, and other components can be described by a screen reader, but such components have to follow coding standards, as custom components do not have built-in accessibility [26]. Today there is a wide range of screen readers to choose between. Menon, Kadukar, Shaikh, *et al.* [27] bring up a lot of different alternatives, such as Seeing AI App from Microsoft, Microsoft Narrator, and VoiceOver.

Using tablets and smartphones as assistive devices instead of traditional tools has

numerous benefits [28]. In addition to superior magnifying and contrast capabilities, they have become ubiquitous in society and are widely accepted as essential tools for everyday living [29], not only for individuals with visual impairment. This means that people with visual impairment do not have to draw as much attention to themselves as they otherwise would, which is important since it has been found that individuals with disabilities are more likely to abandon their assistive devices if they differ from the norm, make them feel excluded or as if they stand out from others.

For visual impairment, the use of smartphone cameras to identify objects through an application can be a suitable strategy to make playing board games easier [1]. Although, a significant issue with this technique is making sure users take the photos according to the instructions of the application. This can be an important issue since the quality of the photos significantly impacts the correctness of the system when recognizing objects. Nevertheless, when an application like this was tested by blind individuals, the accuracy was 75 percent. This technique can therefore be seen as an inexpensive and promising way to assist people with visual impairment when playing board games. For people with low vision or color blindness, it can be especially beneficial since it is possible to customize the corrections according to the users' preferences. One challenge with this technique, and other similar techniques, is the trade-off between enhancing the user experience by making the application specialized and optimal for certain games and types of visual impairment and making it possible to use for a variety of different games and by users with many different types and levels of visual impairment [1]. Filho, Mirza-Babaei, Kapralos, *et al.* [11] highlight the same challenge, that different degrees of visual impairment require different solutions. They suggest including more individuals with visual impairment in the development phase to deal with this challenge.

## 2.3 Optical character recognition

Optical Character Recognition (OCR) is a technology used for converting text in images into digital text[30]. Tesseract, an open source OCR, was originally created by the company HP for their scanners [31]. The conditions when using a scanner can be seen as near ideal and are not the same as a photo taken by a phone or webcam, which also affects the performance of the text extraction making it more difficult. The OCR technology is still improving, and several modern readers are server based and come as a paid service[32].

The procedure of Tesseract's text extraction consists of several steps [31]. These steps include finding and gathering outlines in the picture, using these to look for text lines and a fixed "pitch", a regular spacing, to match letters into. Tesseract also has the ability to read slightly rotated and curved text. Tesseract will try to recognize word by word, following the text lines with the detected fixed pitch, and attempt to train itself with successfully extracted text along the way. Since it then, hopefully, is better at recognizing the text towards the end it will go through the text once more to make use of the improvements. It can also try alternatives to

the originally assumed fixed pitch and formatting, and to repair potentially broken characters.

## 2.4 Convolutional neural network

Convolutional neural network (CNN) is a machine learning model [33], among other purposes used for image classification problems. In such cases, it is common to have the model be made up of several layers after each other which feed information forward, with the first layer getting the image as input and the last outputting the classification. The earlier layers often consist of convolutions and pooling layers which transform the image. Later towards the end of the model, fully connected layers are used which no longer treats the data as an image. Instead, the information flows through each node in a layer to all other nodes in the next. The LeNet CNN can be seen below in figure 2.1.

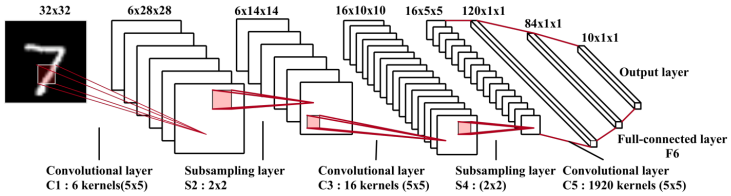



Figure 2.1: LeNet-5 [34], an example of a CNN

## 2.5 K-way n-shot

A traditional machine learning model such as a CNN needs large amounts of training data for its classifications to be accurate [35]. However, in some cases, it is not possible or feasible to gather such large amounts of data. Therefore, **k-way n-shot learning** is an applicable tool for these scenarios since it can do classifications with as low as one data point for each class [36]. These samples given before classification are called the support set. Furthermore, the k and n in k-way n-shot refer to the number of classes k and the number of data points for all classes n, in the support set. Lastly, when the model is made to classify a data point it is called a quarry.

**One-shot learning** [36] is a case of k-way n-shot learning where only a single example of each class exists in the support set. **Zero-shot learning** [37] refers to k-way n-shot learning where n is equal to 0 which means that there are 0 real examples per class. To remedy this, data points are estimated, fabricated, or described in some kind of way. The last of the k-way n-shot model kinds is the **Few-shot learning** [36] model which can utilize several data points for each class in the support set.

## 2.6 Prototypical networks

A prototypical network is a kind of few-shot learning model for, among other purposes, image classification [38]. It works by transforming an image into a feature vector. Since this vector is meant to represent the image, images that are similar would in theory have feature vectors with low distances between one another. Furthermore, Snell, Swersky, and Zemel [38] expands this idea by proposing prototypes which are the mean of several of these feature vectors of images from the same class. Following these ideas, a model is trained to minimize the distance between each prototype and quarry images of the same class as the prototype. The authors claims that such prototypes give the model a better accuracy when distance is calculated with Euclidean distance compared with no such prototypes and using the cosine distance.

Prototypical networks are a kind of meta learning model [38]. Furthermore, Meta learning model are *taught* to *learn* how to achieve a goal [39] instead of how to achieve a goal directly. Nevertheless, just like all machine learning model [40], prototypical networks also need training data to learn and test data to be evaluated. But the difference is that data points are instead episodes [38] which are made up of a quarry set and a support set. The model's performance will be determined by how many data points in the quarry set could be correctly classified after the model was introduced to the support set, for each episode. Thus, the prototypical network model can be optimized to increase this accuracy in overall training episodes. Afterwards, when the training stage is over, the model can be tested with the testing episodes.

Going forward, training a prototypical network has an advantage [38] over none episodic training due to the nature of episodes. The reason for this is that the selection of data points from the available data set for an episode is to some degree arbitrary. Therefore, the training set and testing set can be extended with further episodes by making new combinations of data points from the available data set.

# 3
# Methods and Implementation

The methodology section outlines the steps taken by the group to develop the desired application. In Appendix A, a **timeplan** is presented using a Gantt chart and a table is provided showing all deadlines for the course. After having an overview of the course structure, the next step was to set up a workflow and it was decided an agile work method called scrum would be used, see Appendix A for more information.

## 3.1 Research study

Initially, a lot of resources were focused on researching the subject. The group knew from sources such as articles that were mentioned in related work 1.6 and their supervisor that this subject was relatively low researched. Therefore, it was seen as important to quickly acquaint oneself with the existing research, in order to know what kind of knowledge was missing. The group sought to supplement the existing research with research from primary sources, such as interviews, to fill in these knowledge gaps. The overarching goal was to use different kinds of sources, both regarding research and interviews, to get different perspectives and opinions.

The group used the research questions as a starting point to build a structure and gain an overview of the necessary research. Each research question as they are listed in section 1.3 was tackled on its own and a plan was made on how to collect the needed knowledge.

### 3.1.1 Research of user-friendly design

The application consists of many different areas that all needed to be designed to make it user-friendly for people with visual impairment. Some of the identified areas included which colors to use, how to design the interactive elements, and how to present the text of the cards. There was a relatively high amount of existing research in these areas, although many of them were not from academic sources. Even though academic sources are recommended to use in a report, an evaluation of the different kinds of sources where made for this specific subject. Since the application is made for people with visual impairment, sources from people who are visually impaired, or have direct experience working with individuals who are, were seen as more valuable for this project. One of the sources for this information was the website for Synskadades Riksförbund (SRF), which translates to The Swedish Association of the Visually Impaired. SRF is a non-profit interest organization for people with visual

impairment and parents of children with visual impairment. Since this organization consists of people with visual impairment, which is the main target group for the application, it seemed beneficial to use information from this source. Other sources that were found useful were some videos on Youtube, for example about accessible user experience (UX) and user interface (UI) design. Since YouTube can be an untrustworthy source, the creators of relevant videos were looked up, for example on LinkedIn, to make sure they had the right experience and knowledge on the subject. The Web Content Accessibility Guidelines (WCAG), which is the standard for accessibility, were also looked up, with the intention of following relevant criteria in the project.

To get first-hand opinions from people with experience in using applications designed for the visually impaired, some information regarding design was gathered through interviews. The results from the interviews are presented in section 4.2.

### 3.1.2 Research of features and functionality to include in the application

Google Scholar and Semantic Scholar were used as search engines for research regarding features and functionality to include in the application. To find relevant information on this, searches were made about what the main problems are today for people with visual impairment when handling cards in board games. What functionality and features existing accessible devices have that can be used when playing board games were also researched. It was troublesome to find relevant information about this since, as previously mentioned, the subject of visual impairment in combination with board games is relatively low researched. It was also decided that this information could be more valuable coming from people with experience in the subject. The group, therefore, decided to collect most of this information through interviews with people that had knowledge on the subject of playing board games with visual impairment.

### 3.1.3 Potentially useful ways to digitally identify cards

Scientific research related to methods to digitally identify cards was more accessible compared to the other two areas as the methods themselves are not specific for the purpose of this project. Nevertheless, some methods were complicated and lacked simple explanations as some of the methods were relatively recently discovered.

This research was done iteratively, both from the perspective of improving the identification results and adapting it towards the findings as the research in the other areas progressed, with the sources ranging from developers' blogs and guides to scientific reports. As a result, the research related to identifying the cards was continually refined to align with the desired functionality of the application.

## 3.2 Interviews

With the hope to collect information about some design choices and important features and functionality of the application, three interviewees with different backgrounds and knowledge on the subject were selected. The interviews were conducted in a semi-structured format with some open-ended questions to make it possible for the interviewees to steer the interviews in a certain direction and share what was most important to them.

The first selected interviewee was an administrator at SRF. This interviewee was chosen because of their experience of working with people with visual impairment and interacting with individuals with different types of visual impairment. This interview was conducted through email since that was the preference of the interviewee. The questions focused on the scope of the application and on what features to include.

The second interview took place in a cafe with a headmaster of a special needs school. This interviewee has experience working with children with visual impairment. Their experience involved, for example, assisting them in board game playing and seeing how they work in a group. Therefore, this interviewee had knowledge about everyday challenges that can occur for children with different types of visual impairment and strategies to make their daily life easier. The questions for this interview were focused on what difficulties children with visual impairment usually encounter when playing board games, how they deal with these problems today, and what the most important features and functionality to have in the application are.

The third and final interview was conducted with a member of Sverok, a Swedish non-profit organization that aims to promote and develop the gaming culture in Sweden. This particular member was visually impaired, having both cataracts and glaucoma, and therefore had unique insights on playing board games with visual impairments. This interview was conducted via telephone since that was preferred by the interviewee. The questions for this interview concentrated on how well existing assistive tools work for board game playing, what characteristics a good and user-friendly application has, and what important features to include in the application.

## 3.3 Development of the application

To develop the application the group first had to decide what form of application it would be and have a rough idea of how it could work to achieve the intended goal of identifying and presenting cards. Following these decisions prototypes and proof of concepts could be made to show that the ideas had potential to work. First after this, the bulk of the development could start.

### 3.3.1 Game choice

The website *Meeple Like Us* [41] produces board game reviews and game accessibility analyses and has a master list that describes games' grades with respect to accessibility factors such as color blindness, memory, communication, and rating, as well as visual, physical, and emotional accessibility. Based on that, a game named "The Settlers of Catan", with a somewhat high yet not perfect grade in the visual accessibility aspect, was chosen to start this project's application testing. It has cards with a somewhat small text, the text does not always have great contrast and the font can be difficult to read. Another reason for choosing Catan is that it is a common game to start with when getting into the board gaming community.

Catan is a multiplayer board game where each player tries to build settlements, roads, and ships and upgrade settlements to cities. Building and developing holdings require resources. Resources can be gained either by trading or by building holdings beside terrain types. Their production is stopped by placing a meeple signifying a robber on top of the terrain tile. Some of the other components in the game are development cards, for example, the "Knight" allowing the player to move the robber, and victory point cards that bring the player closer to the winning score.


(a) Catan boxart (b) Catan players

Figure 3.1: The Settlers of Catan [42]

### 3.3.2 App or web app

To decide whether to develop an app or a web app a comparison between the two was made. An app is designed to run on a device such as a smartphone or a tablet and on an operating system such as Android or iOS, unlike a web app which is designed to run in a web browser. Both apps and web apps may run either offline or require a connection to the internet. An app needs to be downloaded and installed, while a web app can be accessed just through a link [43]. Apps require regular updates to keep up with changes in the operating system yet web apps can be updated instantly because they are hosted on a web server. Some consider apps to be more trustworthy due to the need for testing and approval from app stores. To finalize, both sides have their pros and cons, but the group chose to develop a web app in

the end since it can easily run both on iOS and Android.

### 3.3.3 Potential card identification methods

Since the primary purpose of the application is to present card content in a more readable format, it was clear from the beginning that a method for identifying cards would be necessary. A few different options were initially considered for achieving this: NFC-tags, QR-codes, AI image recognition or using OCR to read the text. Out of these, QR-codes were quickly dismissed as NFC-tags seemed similar in procedure, requiring a physical attachment to the cards, but more promising as the scan is proximity and not aim-based.

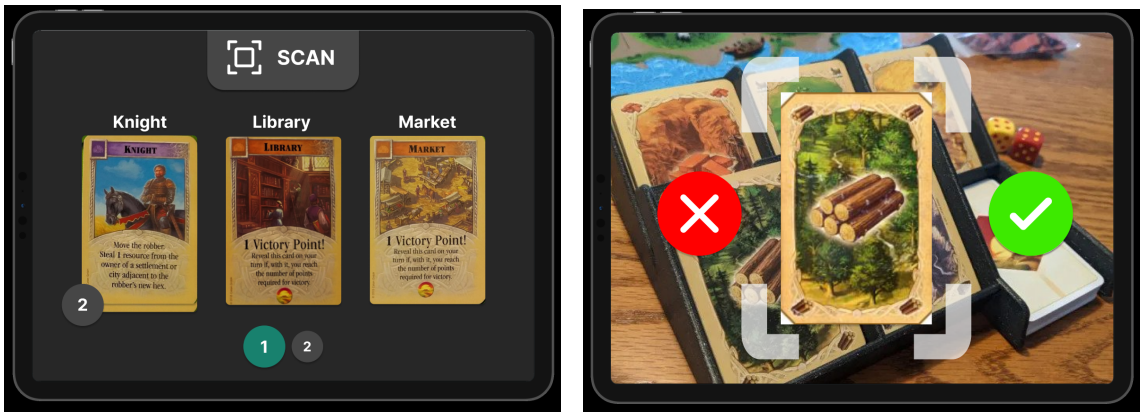
With the NFC solution, the cards could be scanned by simply holding a phone close to it which could reveal information about the card the tag was placed on. This would however require the user to place tags on every card of the board game before the application could be used, making it less spontaneous to play. It would also be less scalable as each copy of a board game would require this modification to be made. Due to these limitations, the decision was made to further explore the two remaining methods, the use of image recognition and OCR.

### 3.3.4 Prototype and proof of concepts

The group started the development process by making a prototype of the intended application and a proof of concept of the card identification methods.

A prototype representing the visual aspects of the main functions of the app, primarily the functionality to identify, display, and store cards from the board game Catan, was developed in the design tool Figma, which makes it possible to simulate some interactions between the user and the prototype. The process for developing the prototype was that each member of the group created a small first sketch of the application. Then these sketches were discussed in a meeting where a rough design was decided on. A few group members then continued to refine the prototype, which served as the foundation for developing the application. In figures 3.2a and 3.2b a sample of the prototype can be seen. Ideally, the prototype would have been shown to, and evaluated by, one of the interviewees but since this was not possible it was shown to the group's supervisor who has some knowledge of the subject of visual impairment.

In parallel to the prototype of the design, the group developed a proof of concept of card recognition as it was another core aspect to make the app work. This was done in two parts, one for image recognition, and one for text recognition, both done in Python. This was to test the potential of identifying the cards through these methods before continuing with the project.



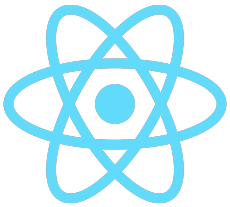

(a) Card page (b) Scan page

Figure 3.2: Figma prototype

## 3.4 Frontend

The frontend was designed with focus on accessible UX and UI, using the tools presented in the following section.

### 3.4.1 Tools




(a) React [44] (b) HTML [45] (c) CSS [46]

Figure 3.3: Technical tools logos

**ReactJS** is an open-source JavaScript library that is commonly used to build UI [47]. React makes the process of building complex UIs simple by breaking them down into smaller components as JavaScript code snippets. These components are reusable and the building blocks of the UI [48]. A document object model (DOM), is a representation of a page in a web document. A virtual DOM is a virtual representation of the DOM, and when an element is changed, only the virtual DOM is updated, but is later synced with the actual DOM using the library ReactDOM [49].

**Hypertext Markup Language (HTML)** is a structural language that is used to give web pages their structures. HTML gives the authors means to structure pages with basics such as headings, text, tables, and photos [50]

**Cascading Style Sheets (CSS)** is a language that describes the presentation of a document or web page, such as color layout and fonts.[51] CSS can make the presentation of a page able to work both on devices with a smaller screen, such as a mobile phone, or one with a larger screen such as a tablet[50]. The *Cascading* in CSS stands for the fact that the presentation of a document can be influenced by several style sheets, a set of rules solves conflicts when different sheets try to set the value for the same element or property [52].

### 3.4.2 Development of frontend

The start of the frontend development was done in parallel with the more detailed Figma prototype and further development of the image recognition after the first proof of concept. The initial idea was to have all of the app's functionality running in the browser. Thus, Tesseract together with some mock card- and hand-functionality was set up as a base. But as complications arose from attempting to run Python code for the identification functions in the browser, as well as from implementing similar functionality in JavaScript, the plan eventually changed to include a backend for these functionalities.

The frontend, made in ReactJS, was seen as a critical aspect of the project since it serves as the primary interface for users. Given the project's motivation, to make it easier for people with visual impairments to understand the content of cards, it was essential that the frontend presents the content in a clear and accessible way. The design and implementation of the frontend required certain attention to ensure that it effectively communicates the necessary information to all users, serving as a link between the user and the functionality split between front- and backend.

### 3.4.3 Design for the user

It was also seen as highly important that the application was as easy to use as possible. For this to be achieved, it was considered important not to include any unnecessary steps that the user had to go through, and that it was easy to navigate through the application. To achieve this, the group decided to aim for a clean and minimalist design with only the most necessary features, to avoid disorienting the user with too many buttons or other visual elements.

The fact that part of the target group uses screen readers was something that had to be kept in mind. As far as possible, semantic HTML was used, where the element's meaning is described to the browser. This allows screen readers to better describe the content on the page [53]. Since creating accessible components can be difficult, a library called react-aria was used. React-aria is a library for React that makes it easier for developers to design accessible user interfaces [54]. The library consists of a collection of components that follows the WAI-ARIA, Accessible Rich Internet Applications Suite, and authoring practices. It supports mouse, touch, keyboard, and screen reader, as well as keyboard navigation support.

Since many people with visual impairment change their font settings on the web, the application was made using relative units when setting the size of different objects such as buttons and text. This makes the application more accessible since the settings of users who have changed their web settings do not get overruled. To make the font easy to read, [55] guidelines for an accessible font were followed.

The number of different pages was minimized to make navigation as simple as possible, and the layout tried to imitate how it would look if the player had physical cards in front of them, to make the app more intuitive.

## 3.5 Backend

For the application to be able to identify cards that were scanned, a backend was developed. The intended functionalities of the backend were card identification and providing the frontend with game-related content stored in a database.

### 3.5.1 Tools

Flask seemed to fit our needs for connecting the backend with the frontend, since it is compatible both with Python and the React application via an API. For the database, mongoDB was chosen for its simplicity to use. The two card identification methods, text recognition and image recognition, were then further developed separately and an API to handle communication between the frontend and the backend evolved.


(d) Flask [56]


(e) MongoDB [57]

Figure 3.3: Technical tools logos

**Flask** is a Web Server Gateway Interface (WSGI) Python web application framework [58]. It's a lightweight framework known for its simplicity and flexibility, making it a popular choice for building small to medium-sized web applications.

The application needs to provide support for the diversity of different board games, which means that the database needs to be flexible. **MongoDB** is a document-oriented database where the data fields can vary between documents. It is an open-source NoSQL (Not only Structured Query Language) system that provides high flexibility, scalability, security and availability [59].

### 3.5.2 Text recognition

It was decided that when a card is to be identified by text recognition in the project it should be done in three main steps. First, the image should go through prepro-

cessing to prepare it for the following step. In that next step, optical character recognition needs to extract the text from the image. Finally, the extracted text has to be matched against the text of the cards in the selected game to determine which ones it resembles the most.

For the preprocessing part of the procedure in the project, the uncertainty of the quality and dimensions of the picture the backend would receive made the construction of a pipeline more difficult. Too high resolution made the preprocessing of the picture slower as it had more data to process. Too low resolution and the text becomes illegible. In addition, the more steps that were added to the preprocessing the slower this part of the process got, while it on the other hand, if successful, could speed up the OCR performance.

For this reason, images were grayscaled and it was decided that large pictures should be rescaled down to a predetermined size. The size was based on a subset of test images which had decent results while keeping down the processing time, but this could be refined further. This is done both to fit the images to a pipeline made for one size of pictures and to speed up subsequent steps. The image is then denoised with dilate, where a pixel's value is set depending on surrounding pixels, and thresholds are used for converting the image into pure black and white to remove noise and make the text more clearly distinguishable from the background.

When the transformations are done the image is sent to the frontend to be run through Tesseract, which extracts the text and returns the result to the backend.

Since the sought-after texts are known beforehand in this project it makes use of the so-called "bag of words" strategy which is based on having a dictionary to match the documents against and transform the text into feature vectors. These vectors keep track of the word occurrence of the words from the dictionary that appear in the text but ignore the position of the words. Both the corpus and the later provided texts are transformed into these vectors and they can then be compared to estimate their similarity.

After extracting text with an OCR it's common to have a step correcting minor character errors in the text which also were included. For this project, it appeared fitting to use the dictionary created by the corpus of cards. After filtering out special characters in an OCR read text it is run through a light spell correction. Its aim is to check word by word if any of them are one character away from a word appearing in the dictionary. When the correction step is done the text is made into a vector, as mentioned above, and can then be compared to those of the corpus to find the best matching ones.

### 3.5.3 Image recognition

Traditionally, a CNN is trained on large amounts of image data [35] before it can classify new images. Moreover, the project group aimed for the app to be extendable

by users with new board games. For that to work, the users would have to train the model for the new board game as the project group could not train the CNN for all possible board games before the app was released. But this would be too challenging for the users due to the large data requirements. Because of this, alternative image recognition methods were sought after, and k-way n-shot learning, see section 2.5, was found. This method could classify with drastically less data. Finally, there are several types of k-way n-shot learning of which the project group choose few-shot learning to utilize its accuracy increased for larger support sets.

The project group came to the conclusion that it was not viable to train their own model. The main reason was that it would require large amounts of data to do so, which was outside the scope of this project. As a result, the research group sought a pre-trained few-shot model. Even so, no such model was found. Instead, an article by Safka [60] was found which had example code showing how to transform images to feature vectors. It does so by extracting the second last activation layer in a CNN model after it has been fed the image. This was significant because it could extract a vector each from two images, between which the cosine distance could be calculated which indicated their similarity. The research group expanded upon this code by implementing a simple few-shot classifier by comparing pairwise cosine distances between support vectors and the quarry vector. Going forward, it is sub-optimal to classify pictures by the highest cosine similarity in the support set [38]. Therefore, the research group instead created prototypes based on feature extractions by the CNN model and followed the design described in the paper.

Later on, it was discovered that the previously mentioned article was linked to a library [61] which streamlined such feature vector extractions from 16 CNN models. This meant that classification accuracy could be improved by picking the best model among the 16.

As the project progressed, the accuracy of the best model was found to be insufficient as it only achieved 81.6% accuracy in a 9 way 10 shot setup. Although, the model could not be improved by itself since it was pre-trained. It was then the idea came to not only create prototypes for the support set but also for the quarries. Or in other words create quarry prototypes, see figure 3.4. This means that instead of classifying a single picture several are classified as a set. Importantly, it is assumed that all pictures are of the same class in the same quarry prototype as only one classification will be made.

This was implemented by first calculating the quarry prototype. Then the prototype was classified as if it was a normal feature vector. This resulted in higher accuracy but longer classification time which is expected as it takes time to vectorize each picture. As a baseline, see figure 3.5, the soft max classification for each image from the quarry prototype was averaged. The reason for this baseline is that its approach works on all models with a soft max classification layer. Thus, if the new method with quarry prototypes does not exceed the baseline it should be disregarded.

$$soft\_max[\frac{1}{|Q_{set}|}\sum_{x \in Q_{set}} vectorize(x)]$$

Figure 3.4: Expression for calculating a quarry prototype's softmax distribution

$$\frac{1}{|Q_{set}|}\sum_{x \in Q_{set}} soft\_max\left[vectorize\left(x\right)\right]$$

Figure 3.5: Expression for calculating the softmax distribution for the baseline method

$Q_{set}$: the set of quarries to be classified
$soft\_max$: the softmax classification function made by the prototypical network
$vectorize$: function to turn a picture into a feature vector

Because of this, a choice had to be made on to what degree time and accuracy should be prioritized. The solution to this was to simply let the user determine how many pictures they wanted to take. By doing so, they can increase the expected accuracy with each new picture taken at the cost of extra time. Although, because of time constraints, this was never implemented in the frontend of the app and is therefore currently unavailable to users.

## 3.6 Test of using the application

After a minimal viable product had been developed, the group tested the application a first time during real game play. The test was conducted by each participant having the application on their phone, taking a picture of each new card that was added to the player's hand, and playing it in the application at the same time as it was played in the physical game. This first test was only done with image recognition as the identification method since the focus was on evaluating the interaction with the application. The feedback from the test was then used to improve and make the app more user-friendly for the next test.

After addressing some of the issues discovered at the first play test and finalizing a combined text- and image identification setting, a second test was done. For this test, the focus was moved toward the card identification methods. Half of the players tested with image recognition only and the others with the combination of image- and text recognition, with results noted down, to compare their performance.

# 4
# Results

The result from the project consists of two parts: research findings and the developed application.

## 4.1 Research findings

The research findings from the research study presented in section 3.1 are summarized in table 4.1 below. The result is divided into three different categories; how to present text in an accessible way, how to think about color and contrast, and how to design interactive elements.

Table 4.1: Research findings

| **Text representation** | **Color and contrast** | **Interactive elements** |
|---|---|---|
| clear and simple font, avoid light or script fonts [55] | individual preference but colors should be contrasts [55] | expressive link wording [62] |
| large text size, minimum size 14 [55] | yellow on a black background makes good contrast [55] | explain in code what roles the elements have [62] |
| bold instead of italics [55] | black, dark blue or green on a white background makes good contrast [55] | use the element em to emphasize since screen readers can communicate that [62] |
| avoid uppercase words [55] | contrast ratio at least 4.5:1 [63] | underline text to show that it is clickable [63] |
| line spacing to points larger than text size, maximum 18 points [55] | never depend only on colors, complement it with other strategies [62] | write alt-text for buttons with icons [62] |
| line length should be between 6-13 cm [55] | be especially careful with green, red and brown [55] | use responsive design [62] |
| spacing between letters and words not too wide nor too tight [55] | make color options and modes available [62] | make undo clicks possible [62] |

Most research on text representation resulted in self-evident findings, which ultimately add up to two key goals: making the text as clear as possible and aiding the

reader in identifying where words and lines begin and end. For example, using all uppercase letters can make it harder to merge letters into words, and appropriate spacing, both between lines, letters, and words, can highly affect the ability to separate words and increase the reading flow [55].

The research on colors and contrast did not yield as clear recommendations as text representation. This is because which colors and contrasts are most suitable is highly individual [55]. For example, some people prefer white text on a black background and some prefer black text on a white background. Since colors can be hard to distinguish, it is recommended to never depend only on colors to communicate something but to complement it with for example icons and different frames [62]. However, it is not recommended to discard using colors as a communicator since it is helpful for those who can differentiate them. The conclusion for the color and contrast research was to aim for high contrast, use a contrast checker and only use contrasts with a ratio of at least 4.5:1, and keep in mind that preferred colors are individual.

Most findings on interactive elements regarded how to make them compatible with screen readers, although it was emphasized to keep in mind that all users will not have a screen reader so the interactive elements have to be understandable through graphics as well [62]. One important functionality is to be able to undo clicks since people with visual impairment have a higher risk of accidentally pressing the wrong button [62].

## 4.2 Interviews

Below is a condensed overview of key factors from the three interviews that hold relevance for the application. The complete interviews can be found in Appendix B.

### 4.2.1 Administrator at SRF

In the interview with the administrator at SRF, several valuable features and important considerations were discussed that could be included in the application. These include:

- Making the application user-adjustable, for example by using different views such as miniature cards that can be selected to display full-screen versions, since different users have different needs "If one wants to create a good app, it is, therefore, valuable to see how it can be adapted to the players' needs"
- Include a dice, "In many board games, dice are rolled. Can it enhance the players' experience if they can roll a die directly in the app?"
- Make it possible to switch color mode, for example, light or dark mode, and possibly choose which color code you want
- Implementing different types of items, such as a money feature that allows users to add and subtract funds and obtain a quick overview of their financial situation

### 4.2.2 Headmaster of a special needs school

The headmaster explained that when they play games with children who have visual impairments at the school, they usually play digital games and make adjustments "We play mostly digital games, like digital memory where we enlarge the pictures and change the backgrounds to create different contrasts. Red- and black is a good combination- it is also the first colors we see". When they play non-digital games, a difficulty for children with visual impairment is keeping up with the game, knowing where the pieces are and what they are, and rolling the dice. To deal with this at the school, they usually have someone from the staff sitting next to them, telling them everything that happens. This is because it's easier to get all that information from the same voice, but also to make it easier to focus on having social conversations with the other players so that there is a division between the social and informative aspects "It is easier if it [the information] comes from one separate voice and the child can focus on social conversations with the others instead".

The headmaster also said that many people with visual impairments have experienced social exclusion. Especially those who have acquired visual impairments later in life "Some students have never been able to see, others get a visual impairment later in life and it is much harder for them. It is easier to compensate for it if it was there since birth. Those who acquired it later in life have a harder time. Socially as well, they are often more fearful and insecure".

Suggestions for the application included adding text-to-speech functionality, which is also beneficial for the elderly, carefully considering color schemes, and optimizing it for tablet devices, which are the primary digital devices used by the children at the school.

### 4.2.3 Member of Sverok

The member of Sverok said in the interview that the most challenging aspects of board games often are related to the visual factors of the cards and the board. Especially if the text is small. Contrast was also brought up "Contrasts such as black background with yellow text ... provide good contrast, so work with contrasting colors overall".

It was also discussed in the interview what would make the application as good as possible. The interviewee said that it should be able to recognize many different kinds of cards "Ideally, it should be able to work for as many different forms of card as possible. Because I've seen apps that are great, like one I use when I play magic sometimes ... but it doesn't work on other cards. It needs to be something that can detect different cards in a good way and read them and recognize text".

Given design suggestions included using clear icons and clear text, and being careful not to make the application too cluttered. The importance of contrast was also brought up, and it was stated that it would be beneficial if it was possible to switch between different contrasts such as dark mode and light mode. It would be good

if the application could detect if the phone using the application was in light or dark mode. The interviewee preferred using a phone but thought it was best if the application was suitable for both a tablet and a phone.

## 4.3 The Application

The first page to be entered in the application is the front page, which consists of a button for starting a new game, a button to continue an ongoing game, and a settings button.

If a user chooses to start a new game, they are redirected to a page where they can choose which game to start. The only game currently available is Catan, but it is possible in the future to expand the application to include additional games.

### 4.3.1 Settings

The different types of visual impairment can affect a person's sight in different ways, which the application had to reflect. By making it possible for the user to change both the theme in terms of colors and the font on the application, the user can choose something that works well for them. The default is the high contrast mode, with yellow and black, as was found in the research findings section 4.1, with a contrast ratio of 19.55:1. This high contrast mode might not be the most pleasing to the eye, so two other modes, one light and one dark, was also added. Even though the contrast is not as high in these two modes, the colors still pass the WebAIM contrast checker. These three modes can be seen in figure 4.2. The possibility to switch between different themes was seen as important since it was both brought up in two of the interviews and found in the research as an important feature.

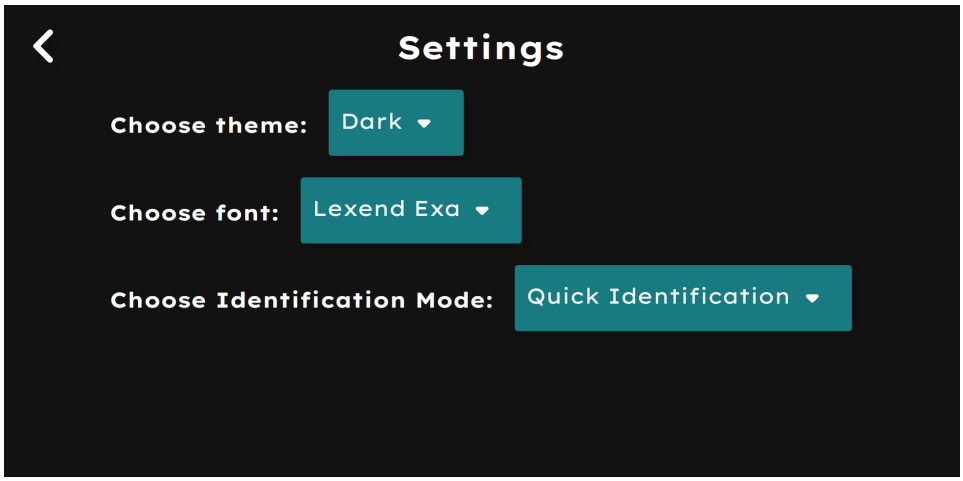



Figure 4.1: Settings page

There are three selectable fonts in the application; Lexend Exa, Arial and Comic Sans. Lexand Exa is a font with straight, clear and simple letters that is easy to

read and made for people with dyslexia [64] and Arial and Comic Sans are said to be preferred by many people with visual impairments [65].

The third setting is the possibility to switch between dual and quick identification, which means that the application uses both image and text recognition, or just image recognition. The results of the two methods are presented in section 4.4.

### 4.3.2 Main page

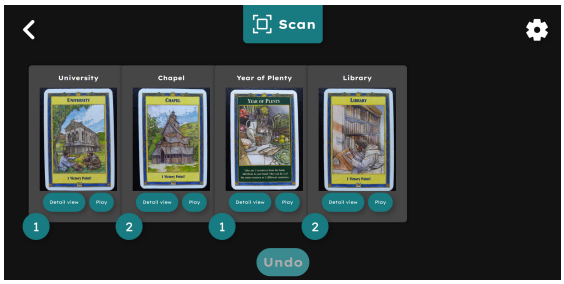
When a game is started, the user is redirected to the main page. This page is the main part of the app, where all scanned cards are shown in a hand, and can be scrolled through. A reason for including the hand was that in a test with people with visual impairment using cards identifiable through touch, it was shown that they throughout the game repeatably checked their cards to form strategies [11]. Therefore, it seemed useful to include the possibility of checking the cards on hand whenever.

The cards are shown as images with their titles, as well as buttons to play the card, and an option to go into a detailed view of the card. When a card is played, it is removed from the hand, and an undo button lets the user bring it back to the hand if it was mistakenly pressed. The cards can be reordered in the hand in any way the user wants to, but the default is that the newest card is added first unless it is the same as another in the hand, then these are grouped together. At the top of the page is a "Scan" button, which opens a camera view, where the user can take a picture of a physical card. The picture is then sent to the backend to be identified. If a match in the database is found, this card's detail view is shown, with the option to discard the card or add it to the hand. This makes it possible for a user to quickly read a card when needed, and could be useful for users with better vision that wants to use the application more sparsely, and not store their entire hand digitally.

### 4.3.3 Detail view

As mentioned previously, the user can press on a card in order to show a detailed view of the card. The card is shown alongside all the content in terms of the text on the card, with a high-contrast background to make it easy to read. For users with screen readers, the text can easily be read aloud, since the text is already extracted from the card.

To improve the gameplay there is a button to increase or decrease the number of the specific card. The detail view is shown above the hand so the user can see both the hand and the detail view at the same time, and if wanted, the user can easily hide the detail view by pressing the hide button or the area outside the detailed view. The number of copies of the card is represented by a number in a bigger font in the bottom left corner.




(a) Dark mode main page


(b) Light mode main page


(c) Yellow and black main page

Figure 4.2: Themes

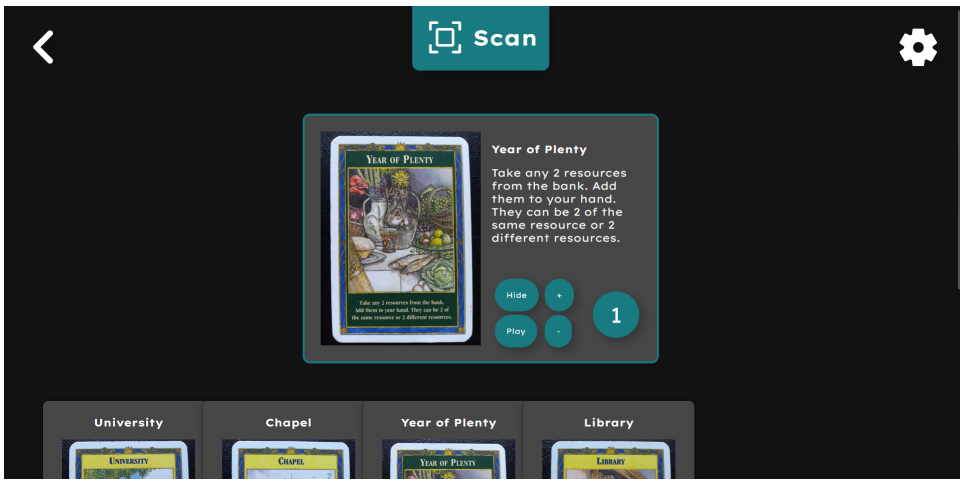



Figure 4.3: Detail View page

### 4.3.4 Alert

To improve UX an alert box was implemented, which shows up when the user performs an action that changes the cards in the hand. The alert informs the user of the performed action and in that way makes it easier for the user to keep track of their actions, intended or not, without interrupting the use of the application. This makes it easier for the user to know when they accidentally have played a card and should use the undo-button. Another idea could have been to use a control question instead of an alert when playing a card, but the decision was made to implement the undo button and alert to keep the application from having more steps than necessary, which would reduce the flow.

### 4.3.5 Implementation of React Aria

The library react-aria was used for many of the more generic components, like buttons and drop-down menus. The react-aria library satisfies most of the identified functionality needed for interactive elements. If a user uses a screen reader and wants to choose a game with the drop-down menu, the screen reader will be able to describe the component so that the user knows what each click or touch means. For buttons with only an icon, an Aria label is passed to assistive technologies so that the button can be identified [66]. Since React Aria only provides the functionality of the components, they were still customized to fit in with the other self-built components.

## 4.4 Card identification

The card identification in the project has two approaches; text matching and image identification. Their performance was compared and evaluated to find the most suitable solution for the application.

### 4.4.1 Text matching performance

To identify the card using only text matching turned out to not be efficient enough, with an accuracy of 67% in a performance test involving 152 images of cards from Catan, see table 4.2. In the test, the majority of the images were of cards turned in the correct direction and fairly well-focused. Still, the test also included images with tilted camera angles, varying distances, and rotated cards. One reason for the text matching being less reliable is due to the time needed to identify a card. While it usually takes around 5 seconds, as seen in table 4.2, it can take much longer if the picture is taken with other text-like elements, besides the card, in the background. Another reason for it being less reliable is because it requires the extracted text to contain a combination of words unique to only one card to be certain which one it is, but it also has the drawback of not being able to handle cards without any text.

Table 4.2: Text matching performance on the Catan cards with text

Card Identification Results

| Correct | Partially correct but inconclusive* | Incorrect | No result |
|---|---|---|---|
| 102 | 23 | 2 | 25 |
| Total Readings: | 152 | | |

Identification time (s)

| Average | Median | Low | High |
|---|---|---|---|
| 5.6 | 5.1 | 1.5 | 19.8 |

| Accuracy | Partial accuracy** |
|---|---|
| 0,67105 | 0,82237 |

**Text matching managing to narrow the possible cards down with the correct card among the remaining, but can't single one out.*
***Accuracy including partial identification*

What it can be used for is to back up the result from the image classification. Even when it doesn't have one unique match it is able to narrow down the possible results for the image classification and, as seen in table 4.2, for cards with text the incorrect readings (false positives) were uncommon. The advantage of this solution comes from the image classification's tendency to be overly convinced of an incorrect result and thus could benefit from potential indications from the text identification method. The resulting findings lead to the implementation of a setting where the user may choose to use only image recognition, which is faster, or a combination of the two which improved the accuracy of the cards with text.

### 4.4.2 Image classification and performance

In this project, it has been shown that a prototypical network does not have to be specifically trained for the purpose of classifying cards to be able to do so. Instead, this learning can be substituted by pre-taught CNN models. More specifically, the library im2vec's vectorization methods can be used as the feature extractor in a prototypical network.

The difference between these vectorization methods was that they utilized different CNN models which meant that they worked differently. Thus, all the models were tested to see which had the highest accuracy. First, the models were tested under a 5-shot 9-way scenario, see figure 4.4, then a 20-shot 9-way scenario, see figure 4.5. Since the model's objective in this project was to classify images of cards from board games it was tested on such a data set. More specifically, 443 images of cards from Catan. These images are of 9 different kinds or classes of cards. Both tests were done with one episode where all pictures not being used as samples were used as quarries. For each episode, the accuracy was calculated.

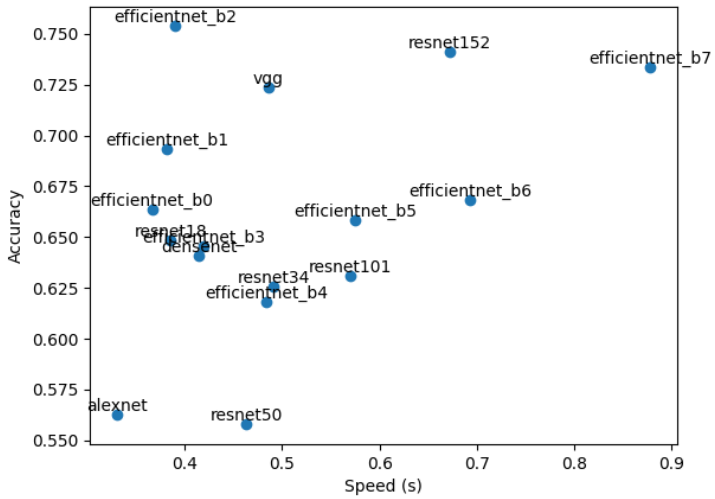



Figure 4.4: 5-shot 9-way results

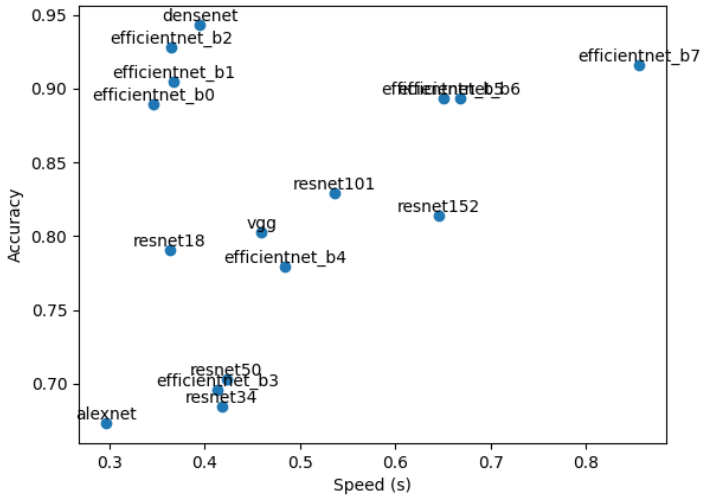



Figure 4.5: 20-shot 9-way results

From these tests, it was concluded that the effientnet_b2 vectorization method was the best as its accuracy scored toward the top in both tests and had a relatively low classification time.

To increase the accuracy of the classification model quarry prototypes, see figure 3.4, were deployed and tested. Furthermore, another test was run on the model, using a baseline method, see figure 3.5. This test was run as the ones before but in a 10-shot 9-way scenario with several episodes, see table 4.3.

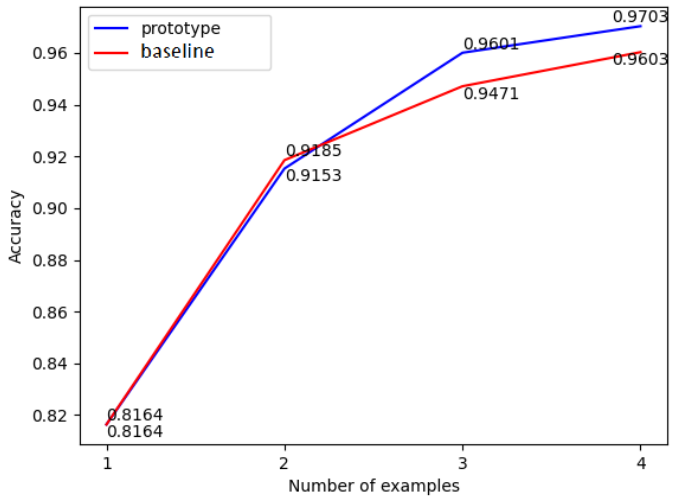



Figure 4.6: Prototype quarries vs a baseline method over several different sizes of quarry sets

The results show that both methods were useful as they increase the accuracy but that quarry prototypes is the better approach.

Table 4.3: Episode sizes for different sizes of quarry sets with effientnet_b2 as vectorizer

| **Method** | **Size of 1** | **Size of 2** | **Size of 3** | **Size of 4** |
|---|---|---|---|---|
| Prototype quarry | 11 | 13 | 18 | 27 |
| Mean soft max | 11 | 10 | 15 | 26 |

## 4.5 Test of using the application

This section presents the result of the two tests that the group did on the application. The results of the first test, which was focusing on evaluating the interaction with the application, gave the following insights:

- If cards of the same type don't stack it's difficult to get an overview of the hand
- Managing both a digital and a physical hand is tedious
- An alert when a card was played out would improve the user-friendliness
- The possibility of undoing a played card, if the play button was clicked by mistake, was a desired functionality
- Adding several cards one by one to the hand is too time-consuming

In the second test, which was focusing on evaluating the card identification methods, half of the players used image recognition only and the others a combination of

image- and text recognition to compare their performance. After reading a card the identification setting and result (correct or incorrect) were noted down. The results for the resource cards also got separated from that of cards with text on them, as any correct readings could only be accredited to the image recognition. If a card was incorrectly read, the terminal output of the backend was checked to uncover the main source of the misclassification.

Table 4.4: User test card identification performance

| Type of card | Image recognition only | | | Text and image recognition | | | Total read |
|---|---|---|---|---|---|---|---|
| | True | False | Accuracy | True | False | Accuracy | |
| No text | 34 | 3 | 0,91892 | 45 | 4* | 0,91837 | 86 |
| With text | 13 | 8 | 0,61905 | 14 | 1** | 0,93333 | 36 |
| All | 47 | 11 | 0,81034 | 59 | 5 | 0,92188 | **122** |

** Two of the misclassifications specifically from random readings from the OCR matching a word from a card.*
*** Card rotated 90° sideways*

The results from the card identification itself, see table 4.4, showed potential issues such as misclassifications from garbled OCR text, and confirmed initial test results from the image recognition's test accuracy.

Reevaluating the UX of using the app, some issues had been partly addressed such as groupings of duplicate cards and the ability to undo a play, which lead to an improvement from the first test, although some issues remained. While the inclusion of OCR increased the time it took to classify a card the testing players thought it to be acceptable. What instead appeared frustrating was the work needed to take and send a picture through the application which was experienced to have too many steps slowing down the procedure. Grouping the cards of a kind together made managing the hand easier compared to the first test, but the issue with two separate hands still remained. Some of the developers found it slightly more manageable as they then could pile cards on the table in the same order between physical and digital hands. Another issue when using the app was that the image recognition method misclassified the cards with text several times. So even though using only image recognition was faster, combining it with OCR gave a more accurate result for the cards with text.

# 5
# Discussion

Below follows a discussion of the results of the research questions. An important aspect to keep in mind throughout the discussion is that the application has not been tested by individuals with visual impairment. This would have been needed before the application would be ready to launch.

## 5.1 Designing the application to make it user-friendly

A wide range of sources and interviews resulted in many aspects and insights. Both on what is scientifically proven to be user-friendly design and what people with visual impairments experience is most convenient for them. Therefore, a lot of information needed to design the app to be user-friendly was available. However, the vast variety of different instructions and preferences made it quite challenging to decide what to include and what to exclude to make the app as user-friendly as possible.

The research showed that certain graphic design choices, particularly those concerning colors and contrast, did not have one definitive answer that would work for everyone. Therefore, three different fonts and several color modes were implemented, although it was not given where to draw the limit on how many modes to include. Including many different modes could be valuable for the user since more people's preferences would be included, but it could also be overwhelming for the user to have too many options.

The first chosen font to include was Lexand Exa since it is supposed to be easy to read. However, it has more space between letters than most fonts have. This can be a problem for people with visual impairment since it can make it harder to perceive where a word starts and ends. Although, too narrow spacing can also be a problem which could make this font preferable. Since the research regarding this did not specify when the space between letters is too wide, it was hard to determine if this would be a problem or an advantage. Therefore two other fonts that were known to work well for many individuals with visual impairment were included as well.

The ability to switch between light and dark modes was mentioned as important in both the first and third interview, hence it was included. In the second interview,

red on black background was recommended, but the research indicated that red was a color that should be used with caution since it can be difficult to make out for someone who is colorblind. This could be an example of when different solutions work for different types of visual impairment. Regardless, red on black was not implemented since it was considered less prioritized than more universal solutions, such as yellow on a black background, which was recommended in both the research and the third interview. This situation exemplifies the dilemma outlined in the theory section: to focus on optimizing the app for certain user groups or strive to make it accessible and usable for a broader range of users. Ultimately, universal solutions were prioritized this time in order to make the application accessible to more people. Maybe it would have been better if a decision was made earlier on in the project about which way to go, whether to aim for a universal application or to aim for the application to be more specialized and suitable for specific types or degrees of visual impairment. This could have led to more consistency in the application and a clearer goal.

## 5.2 Important features and functionalities to include in the application

When developing the application, a number of possible features to implement were recognized, but the time limitation made it necessary to filter out which ones were the most important. There was also a difficulty in balancing the desire to include more functionality to improve the application's usefulness, with the need to maintain a clutter-free, user-friendly interface that is easy to navigate. The most significant challenge here was the fact that different users find different features important.

While a dice function was requested in the interviews, it was not implemented as card elements were the main focus. However, the absence of the dice function may affect usability by requiring users to switch between this application and a dice application, and for a finished product implementing the dice function could improve the application's usability. One might argue that the dice functionality is unnecessary as players can simply communicate the outcome verbally. Although, as shown in one of the interviews, having an independent source of information can help distinguish between the social and informative aspects of the game.

### 5.2.1 Digital hand

During the first user test of the application, a complication from using the app became apparent. In the current form, it requires maintaining two hands, the physical and the digital version, which was rather user-unfriendly and clunky. For example, when a card was played out in the application, that same card had to be found and played in the physical hand as well. This raised the question of which direction the app could continue to evolve in. One approach would be to scale it down and focus primarily on reading in and presenting a single card, while another could include more functionality making the physical hand obsolete. There might not be a single

best answer for that as it might depend on both the game and the player. On one hand, if the game requires swapping cards with other players on a regular basis, or for a pile to be maintained in the right order a purely digital hand might not be plausible. On the other hand, if the app only allows scanning a card important functionality might be lost.

In games like Catan where players frequently swap cards, a digital hand may not be the most efficient option. During the test of the application, it was observed that scanning and playing out cards using the digital hand was time-consuming and caused delays, while the other players had to wait. This suggests that a digital hand may be more useful for games that do not include high card-swapping activity. And even for those kinds of games, for someone who only has mildly impaired vision, the hand function can seem redundant. For someone who has severely low vision, the hand function could possibly still seem redundant.

Even though including the possibility of repeatably checking all cards on hand was motivated by a study [11], it may not have to happen through a digital hand. It is also possible to think that individuals with severe visual impairment may have developed strategies to remember where certain things are or what they mean. One possible solution for individuals with visual impairments could be to scan a card with the application, receive an explanation of the content, and then physically place the cards in a certain order to be easily remembered, the application could then be used to check again on certain cards. This would allow the application to be used only when necessary, saving a lot of time and still keeping the possibility of re-checking cards.

However, as mentioned in one of the interviews, there is often a significant difference between individuals who were born with visual impairment and those who acquire it later in life. Those who acquire visual impairment later may feel more fearful and insecure when trying to compensate for their loss of sight. Hence, individuals who are not used to being visually impaired may have a harder time relying on memorization and occasional checks. In such cases, the digital hand feature of the application may be particularly useful. It is also possible that the time delay in using the digital hand is more noticeable when the application is used by people without visual impairment. Individuals with visual impairment may experience a processing time in comprehending the content of cards without the application as well, resulting in the time difference of using the application not being as significant. However, testing the application with individuals with varying degrees of visual impairment would have made it easier to determine its effectiveness. Unfortunately, this was not possible in this study since the application was not finished early enough to be tested by a test group.

## 5.3 Some potentially useful ways to digitally identify cards in board games

When the group was testing the application, a few misclassifications occurred. For the full-vision developers, a card could be re-scanned if classified incorrectly, but for the target group, this could be a significant problem as it requires the user to be able to recognize a classification being incorrect. Individuals with severe visual impairment or blindness could be completely dependent on the application's classification of a card. If the cards are sometimes misclassified, the game could be highly affected, and the user's trust in the application could be diminished.

Another reason why this problem may be bigger than it first seemed is that when user-testing the application, all users were able to see where the card to be photoed was located in the camera which might not be the case for some individuals with visual impairment. This was a recognized problem with using the camera function even before the application had been developed as mentioned in section 2.2. If the card identification had been made through the use of tags, neither one of these problems would have existed. As long as the right tag was placed on the right card, the accuracy probably would have been 100 percent.

However, a significant problem with the tags method is that the probability of individuals with visual impairment using the assistive device decreases if it makes them stand out or differ from the norm. There is a risk that some people would not want to place tags on all of their cards, and especially would not want to place tags on all of someone else's cards if they were playing at someone else's house. The chance of spontaneity also disappears through this method since the right tags have to be brought if the playing happens somewhere other than at the user's house. The interviewee from Sverok talked about spontaneous playing as something they occasionally do, which points to possible spontaneity being important. So even if the tags method would have been more accurate, it could have made more people discard the application. Perhaps the ability to include both the possibility of using tags and the camera would be a solution to this problem. It would however require much more work developing-wise. Another solution could have been to narrow the target group to either individuals with lower or higher degrees of visual impairment since the camera solution seems to work well for lower degrees and the tags might be more appropriate for people with more severe visual impairment.

### 5.3.1 Text matching discussion

The text-matching method itself mostly remains the same as in the proof of concept but a few changes were made, such as filtering short words from the corpus and making single character corrections of longer words.

The filter focuses on reducing misclassifications from garbled OCR text matching to that of a card. This kind of matching leads to false positive identifications rather than no result, which was wanted to be avoided since it is passed on directly to the

user instead of letting image recognition take over. For the selected game this filter might have been a good approach as these shorter words were not crucial for the identification, but for some other games this might not be the case and could lead to a worse performance and another approach might be needed.

The single character correction instead focuses on increasing positive matches but also raises the risk of false positives which is why it's restricted to longer words and correction by one character. These rules are fairly simple and more optimization could have been made, such as repairing words broken by a space, or another text matching approach, like training a language model on output from the OCR, could have been tested.

To help with card identification, plans were to implement an aim box in the frontend, which would leave it to the user to get the shape of the card in roughly the right spot and pass on its dimensions to the backend. Pinpointing and limiting the orientation of the card would have benefited both identification methods and the image preprocessing, which could have tried basing parameters on image-specific information. The aim box was implemented but the full connection to the backend got left for future work. Another approach could have been to train an object detection model to detect the bounding boxes of a card. The main reason against the latter was the time constraint, depending on how efficient and large already pre-trained models would have been. Therefore it might have required extra training of a chosen model which in turn requires a large amount of training data with cards and their bounding boxes marked out. The idea of an aim box seemed simpler and faster, nonetheless for a finished product the second approach is likely to be better as it puts less of the burden on the user.

### 5.3.2 Image recognition discussion

As stated in the result, the efficientnet_2b vectorizer method had the highest accuracy in the tests, see figures 4.5 and 4.4. The information motivating the decision to use the efficientnet_2b vectorizer method was made on two tests that both had been run on a single episode. The accuracies obtained from these tests may be unreliable due to high variance at low testing amounts. To make a more informed decision, random sampling could have been used to create more episodes for texting thus increasing the test amounts. However, this could take a large amount of time since it took an hour to run a single test episode on all of the vectorization methods.

During the development of the app it was decided that training a few-shot model was too much work. Later on, when the prototypical network model had been chosen, it was discovered that the data needed to train it was less than expected due to the nature of episodic training. This could mean that the task was not as challenging as the project group originally thought. In the paper on prototypical networks [38] two training experiments on such a model were performed with more than 30 000 pictures each. This is still too much data to gather but much more realistic than the tens of millions of images in the data set ImageNet [67] used to benchmark CNNs

[68].

### 5.3.3 Evaluation

For the game and approach chosen in this project, image recognition proved to be more versatile compared to text matching. Besides being both faster and having a wider range of identifiable cards it can also partly handle cards being oriented differently. For cards from Catan without any text, image recognition showed both a decently high accuracy, over 90% in the user test, and a fast performance. For cards with text, the image recognition faltered slightly and a combination of the two methods yielded the highest accuracy, at the cost of slightly longer identification times.

What the project does not tell is if the test result would be similar for all games, as it is likely the current identification procedures are too tailored for the chosen game Catan as well as the specific version of the game. If it had been developed and tried with more games certain procedures might be different. It could be possible that for some games the card elements might be more difficult, or fully impossible for one approach or the other. A game where the card elements have no text would not be identifiable by the OCR approach. Likewise, a game where the card elements look similar but the text differs could potentially be more difficult for image classification. Instead, it might require more game specific identification settings that could have been included in the database and loaded with the game. Therefore, it seems difficult to find a general solution that works well for many different types of games, which was an important functionality according to the third interviewee.

## 5.4 Ethics

Ethical considerations were taken throughout the development of the application. There is for example the virtue-ethical aspect of letting the target group, people with visual impairments, be the main part of user-testing, as well as including people with experience on the subject in the process of designing and developing the application. That was not achieved but it was constantly reminded not to take personal preferences but rather research findings as shown in section 4.1.

The developed application does not save data on the cloud, it is saved locally on the user's phone, which is good from the duty-ethical perspective. That reduces the risk of data breaches and insecurities regarding the integrity of the users. Additionally, no personal information but only the game's status is saved. The application has access to the camera and microphone only when the user has given it permission to do so, and they are only accessible when the application is running.

From the defined ethical perspectives of this project as mentioned in section 1.7, the group deems this project to be one instrumental value to achieve the intrinsic one, which is assisting people with visual impairments to be more included in the board game community.

# 6

# Conclusion and Future Work

This study set out to find a method for making cards of board games more accessible for people with visual impairment, through the use of a digital tool.

It was found that a potential way of doing so is through the use of an application in which the camera is used to photograph cards in board games, which are then presented in a more accessible format. The research revealed that presenting card content in an accessible format for the visually impaired comes with some challenges since the preferences and solutions differ between different types and degrees of visual impairment. This study found that a solution to this was to include the possibility of changing some of the design of the application in the settings so that the user can tailor the application according to their preferences. However, considering the broad range of visual impairments, there is no guarantee that all preferences have been taken into account. The most important limitation of this study lies in the fact that the application has not been tested by users from the actual target group, which for example makes it difficult to determine if enough preferences have been taken into account.

The evidence from this study also suggests that using a digital tool when playing board games can interrupt the flow of the game, and to avoid that, it is important to include as few steps in the application as possible. It is also important that the application is efficient, which was found mainly depends on the speed of the card identification process. However, the results of this study indicate that for the investigated card identification methods, image recognition and text recognition, there is a trade-off between how accurate and how fast the card identification can be on cards with text. This is because a combination with text recognition proved to be more accurate but slower on these types of cards, a method that could be viable in similar situations where matching is done with already-known image- and text-compositions. For the specific target group, this study argues that accuracy is more important than speed and that a combination of text recognition and image recognition is preferred if there are different types of cards in a board game.

Ultimately, the results of this research support the idea that creating a tool for this purpose involves some trade-offs, ultimately requiring a choice between a more universally applicable solution or prioritizing enhanced performance for specific games and types of visual impairments.

## Future work

This section states possible future work inspired by this project. The following features could be worth considering for a similar application in the future:

- Game specific elements such as dice and a rule book could be added to and loaded from the database as the game is selected.
- The image recognition could, in some cases, be extended with the ability to scan areas of the board itself or other pieces related to the game.
- The app could offer translations between different language versions of a game which would have the advantage of keeping the choice of words consistent within the game.

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# A

# Planning

## A.1 Scrum

Scrum is an agile way of working, meaning that the group works in cycles, or sprints, and continuously learns and improves the product. Practically, this is done by dividing the work first into epics, which are broad goals, and then divide each epic into user stories, which are manageable tasks with a clear definition of when it is done. Each sprint the group decided together how many user stories that should be worked on, and who would be responsible for each user story. This sprint backlog with all user stories was in this project managed using the tool Trello. After each sprint, the group reviewed the passed sprint and then decides on the user stories for the following sprint. Using scrum, there is usually a daily scrum, or a stand-up every day, which is a short meeting where every team member presents what they are working on and if there are any problems [69]. That was done in Discord in where a channel for everyday-scrum was used for this purpose.

For the reasons mentioned above, an Agile project management, which is an iterative and collaborative approach, was conducted throughout the project. The framework used is Scrum where the lists "Definitions", "Epics", "User stories", "This sprint", "In progress", "Done", and "Test" were utilized. The epics we had from the start of the project are ...

Weekly sprints with assignments to group members were split and a meeting to two were conducted weekly to make sure everyone in the group are working towards the same goal and that progress is constantly incrementing. Sub-groups where members with different backgrounds were sometimes on purpose gathered to spread the knowledge between group members and make sure everyone to some extent has a baseline of information on each aspect being performed in the project.

## A.2 Gantt chart and deadlines

Table A.1: Gantt chart

| | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 19 | 21 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Research | ■ | ■ | ■ | | | | | | | | |
| Problem formulation | | ■ | | | | | | | | | |
| Project plan | | ■ | ■ | | | | | | | | |
| Proof of concept (AI) | | | ■ | | | | | | | | |
| Prototypes | | | ■ | | | | | | | | |
| Research of user requirements | | | ■ | ■ | | | | | | | |
| Scheduling of interviews | | | ■ | ■ | | | | | | | |
| Final report | | | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| Development and testing | | | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| Data collection | | | | ■ | ■ | ■ | ■ | ■ | | | |
| Half time presentation | | | | | ■ | | | | | | |
| Evaluation of model | | | | | | | ■ | | | | |
| Preview of report | | | | | | | | ■ | | | |
| Report revision based on feedback | | | | | | | | | ■ | ■ | |
| Complied final report | | | | | | | | | ■ | | |
| Film | | | | | | | | | | ■ | |
| Opposistion | | | | | | | | | | ■ | |
| Final presentation | | | | | | | | | | ■ | |

Table A.2: Deadlines

| Activity | Date |
|---|---|
| Initiated project documentation | 2023-01-24 |
| Report language | 2023-02-03 |
| Project plan | 2023-02-10 |
| Half time presentation | 2023-03-07 |
| Personal evaluation 1 | 2023-03-12 |
| Preview of report | 2023-04-27 |
| English title | 2023-05-15 |
| Compiled final report | 2023-05-15 |
| Contributions report | 2023-05-16 |
| Film | 2023-05-17 |
| Individual opposition | 2023-05-22 |
| Final presentation | 2023-05-(25/26) |
| Personal evaluation 2 | 2023-05-29 |
| Final submission, compiled report | 2023-06-02 |

# B

# Interviews

The scripts of the interviews are included in this chapter.

## B.1 Interview with a member of Sverok

The interview was held in Swedish. Below is it's script.
**Får vi använda dina svar till vårt projekt?** Ja det får ni
**Bakgrund till vad vi ska göra: Vår idé är att utveckla ett hjälpmedel för att hantera kort till brädspel. Man ska kunna skanna ett kort, texten skrivs mot annan bakgrund och kan läsas upp.**
**Vad har du för synskada?** Jag föddes med grå och grön starr och därmed ser jag ungefär 35% med glasögon. Jag har varit aktiv inom synskaderörelsen en hel del under min uppväxt. Nu är jag aktiv i Sverok.
**Vad är svårare och enklare att se för dig?** Liten text är jobbig så en hel del kortspel kan vara rätt så jobbiga, och vissa är enklare för att de har större och tydligare text. Kontraster såsom svart bakgrund med gul text, blå, eller vit text, ger bra kontrast, så jobba med kontrastfärget överlag.
**Vilka moment är svårast när du spelar brädspel** Ibland är det korten men det kan också vara spelbrädet, att det är väldigt smått och pluttrigt att se på.
**Använder du några hjälpmedel idag både när du spelar brädspel och i allmänhet?** Jag använder förstoring på datorn och telefonen och även tal. När jag spelar så använder jag ibland telefonens förstoring, deras app magnifyer, för att kunna förstora upp saker och se bättre. Förstoringsglaset tror jag att den heter på svenska. alltså att få uppläst, på datorn och telefonen.
**Funkar det bra med de här hjälpmedlen?** Bra och bra, det funkar bra men inte optimalt. Jag önskar att det fanns något som gjorde det mycket bättre. En ide är att ha någonting som bara kan skanna in det och direkt få upp texten bra eller läsa upp det låter som en väldigt bra ide.
**Har du några tankar på funktioner som kan vara bra att inkludera i vår app?** Helst att den ska kunna funkar för så många olika former av kort som möjligt. För jag har sett appar som är jättebra, som en jag använder när jag spelar magic ibland, dragons hill har en grymt bra där det går att skanna in just magickort och då få upp digital info om den lättare, men det funkar inte sen på andra kort, utan det behöver vara någonting som kan känna av olika kort på ett bra sätt och läsa av och känna igen text. En grej som kanske hade kunnat vara en idé kan också vara att man hade kunnat fota av ett helt spelbräde och då få veta var en del smårutor är, vad dom står för. För det vet jag till exempel när jag spelar Monolpoly med

min storebror och hans barn, vi ser alla rutorna men det är svårt att se vad sakerna kostar för det är liten text. Och då att bara kunna skanna av det med telefonen och bara få det uppläst eller se det större hade kunnat hjälpa otroligt mycket.
**Kan du lista upp några saker att ha i en användvänlig app?** Tydliga ikoner och tydlig text. Inte alltför plottrig. Bra kontrast i appen, bra om man kan byta mellan olika kontraster, och att det ska finnas en "Use system setting", "Dark mode", och "Light mode". Bra om appen kan känna av automatiskt om man har light mode eller dark mode i mobilen. **När vi utvecklar appen behöver vi själva lägga in brädspel som den ska funka för, vet du några brädspel som vi kan böja lägga in** Monopol är ett sånt klassisk spel, seven wonders, ticket to ride, kingdomino, Star Realms.
**Funkar en tablet eller en telefon bäst? Vad föredrar du?** Jag använder telefon väldigt mycket. Om appen kan bete sig dynamiskt mellan telefon och tablet på ett enkelt sätt så är det grymt bra. Det är smidigare med telefonen och man har den oftast med sig när man är ute och spontant ska spela.
**Hade det varit ok att vi frågar mer under projektets gång?** Ja

Below is the translated version of the interview **May we use your answers for our project?** Yes, you may
**Background to what we are going to do: Our idea is to develop an aid for handling cards in board games. One should be able to scan a card, the text will be written against a different background and can be read aloud.**
**What kind of visual impairment do you have?** I was born with cataracts and glaucoma and thus I see about 35% with glasses. I have been active in the visual impairment movement for quite a while during my childhood. Now I am active in Sverok.
**What is harder and easier to see for you?** Small text is annoying and thus a bunch of card games can be quite difficult, and some are easier because they have bigger and clearer text. Contrasts such as black background with yellow text, blue or white text, provide good contrast, so work with contrasting color overall.
**Which moments are the most difficult when playing board games?** Sometimes it's the cards but it could also be the game board, that it is very small and plodding to look at.
**Do you use any aids today both when playing board games and in public?** I use magnification on the computer and phone and also speech, that is, to be read aloud, on the computer and the phone. When I play sometimes I use the phone's magnification, their app magnifies, to be able to zoom in things and see better. The magnifying glass, I think it's called in Swedish
**Do these aids work well?** Good and good, it works well but not optimal. I wish there was something that made it much better. An idea is to have something that can just scan it in and immediately bring up the text well or reading it out sounds like a very good idea.
**Do you have any thoughts on features that might be good to include in ours? app?** Ideally, it should be able to work for as many different forms of card as possible. Because I've seen apps that are great, like one I use when I play magic

sometimes, dragons hill has a really good one where you can scan in just magic cards and then get digital info about it easier, but it doesn't work on other cards. It needs to be something that can detect different cards in a good way and read them and recognize text. A thing that might have been an idea can also be that you could have taken a picture of an entire game board and then find out where some of the small squares are, what they stand for. Because I know that, for example, when I play Monopoly with my older brother and his kids, we see all the boxes but it's hard to see what the things costs because it is small text. And then just being able to scan it with the phone and just having it read or seeing it larger could have helped immensely.
**Can you list some things to have in a user-friendly app?** Clear icons and clear text. Not too plotty. Good contrast in the app, good if you can switch between different contrasts, and that there should be a "Use system setting", "Dark mode", and "Light mode". Good if the app can automatically detect if you have light mode or dark mode in the mobile.
**When we develop the app, we ourselves need to add in board games that it should work for, do you know any board games that we can start with?** Monopoly is such a classic game, seven wonders, ticket to ride, kingdomino, Star Realms.
**Does a tablet or a phone work best? What do you prefer?** I use phone a lot. If the app can behave dynamically between phone and tablet in a simple way, it's really good. It's easier with the phone and you usually take it with you when you're out and about to play spontaneously.
**Would it be ok for us to ask more during the course of the project?** Yes

## B.2 Interview with a headmaster of a special needs school

**Which tools do you know individuals with visual impairment use?** Speech synthesis, reads out text, ClaroRead - digital tool that can be connected to textbooks, both in English and Swedish, OribiWriter - speak and it writes, guide rails and white canes.
**Do you know any games that work well for the visually impaired?** Digital games, enlarged on the computer, for example digital memory where we enlarge the images and adjust for different backgrounds to create different contrasts. Red and black are a good combination - they are also the first colors we see. We haven't purchased any games that are adapted, but instead have made adaptations ourselves, such as coloring the black background with red.
**Which problems usually occur for children with visual impairment when participating in activities such as board games? And how do you deal with these problems?** It's difficult to know where things are placed, difficult to know where the dice is, difficult to know what they and others are getting. Therefore, we have always had a person with us who acts as a describer and tells us what's happening. The participants could have done it themselves, but it's easier when it comes from the same voice, and the child can focus on social conversations with

others instead.
**Which functions do you think would be good to include in an application that reads and handles cards in board games?** Speech synthesis, elderly people can benefit from having someone reading it out. Consider colors.
**Is there something you can think about that would make the application more useful for children with visual impairment in combination with cognitive disabilities as well?** Simplify the language, summarize points, repeat, they can easily lose the thread, "What point was it again?", "What was I supposed to do again?"
**Can you think about something particular to keep in mind when implementing the application, e.g. that is it compatible with other tools?** Ipad is used the most.
**Have you noticed that visual impairment has caused children to experience more isolation and exclusion from some activities?** Yes, some students have never been able to see, others get a visual impairment later in life and it is much harder for them. It is easier to compensate for it if it was there since birth. Those who acquired it later in life have a harder time. Socially as well, they are often more fearful and insecure.
**Do you have anything more to add?** No, I don't think so.

## B.3 Interview with administrator at Synskadades Riksförbund

**We would love to get you input on the actual design of the app, if there are any additional features that may be good to include, and if you know anything else about how the app can be designed to be as easy to use as possible. This could, for example, involve whether it is better to be able to scroll down in the app or swipe sideways to view different cards.**
I have been thinking about your questions and here are some ideas.
An important thing to consider is how the app can work for different people. If one wants to create a good app, it is, therefore, valuable to see how it can be adapted to the players' needs. For example, one could have different views that one can switch between. At level 1, you might see different color-coded thumbnails of card types (such as stocks, house contracts, etc.). If you then go into, for example, house contracts, you can see more detailed information about which contracts you own. In that view, you might choose to see thumbnails for an overview or choose to see each card in full screen and swipe through them.
In many board games, dice are rolled. Can it enhance the players' experience if they can roll a die directly in the app?
Can one somehow create a guide in the app where one can input the rules for different board games?
Can one switch the theme of the app from, for example, light to dark? Furthermore, can one choose which colors to prefer for the game cards in the settings?
Possibly, it could be appreciated if one can create customized item types to keep track of. For example, if I create the type "Money", I can easily add/remove amounts

based on how the game progresses. I can then quickly glance at the overview to see how my finances look."