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Adopting Accessibility Guidelines for Videogames to Collectible Card Games

Cooper Biancur

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Adopting Accessibility Guidelines For Videogames to Collectible Card Games

A THESIS
Submitted for partial fulfillment of the requirements for the degree of
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BY
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Adopting Accessibility Guidelines For Videogames to Collectible Card Games

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Abstract

The development of accessible video games has been discussed through multiple publications in the 21st century; however, little to no attention has been given to non-electronic gaming. Like video games, Collectible Card Games (CCG) have also gained massive popularity, but no accessible guidelines have been created to help the disabled better play them. The need for inclusion in gaming is critical because it can act as a medium for social interaction and a learning tool for teaching. Today offers numerous technologies that can help those with disabilities, such as microcomputers, Artificial Intelligence (AI), Optical Character Recognition (OCR), and Text to Speech, can all be used to help those with disabilities. In this thesis, we create a proof of concept Accessible Technology to help those with low vision play CCG and show that guidelines that worked for video games can be brought over to help with CCG. We use a Raspberry Pi 4B and the Raspberry Pi HQ camera module, Scene Text Detection, OCR, and Text to Speech to read the cards of a CCG. This AT acts similar to a microscope where it captures the image of a card, finds the card’s name, feeds it to a database query, and reads the record from the database to the player. We performed several evaluations where the participant played a game of Yugioh, followed by answering a questionnaire. We found in these evaluations that the AT was primarily successful, and the user problems come from poor text to speech and participants having a hard time remembering or comprehending card information.
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Chapter 1

Introduction

In the 2000’s the attempts at bringing accessibility to video games gained significant interest. [1] This consisted of guidelines being created towards creating accessible games (AG), adoption of testing methods, and adaptation of accessible Graphical User Interfaces(GUI) and AT. These efforts showed good techniques that can be improved on and brought to other gaming genres. The Collectible Card Game genre (CCG) is similar to other gaming genres of the modern era in its spike of popularity and a mechanism for learning. These similarities to video games spark the question of how similar techniques can make CCG accessible to those with disabilities. This paper only looks at making CCGs accessible to the visually impaired and applying new technologies such as neural networks, databases, microcomputers, and text-to-speech engines to create an AT. We ask if similar techniques and practices can be improved or incorporated into the CCG genre.

1.1 History

Today accessibility to all might seem like an obvious concept, yet it was once a very foreign idea in Western civilization. A large portion of the blame can be given to the Eugenics movement that hit America in the early 20th century. The term was first coined by Sir Francis Galton, a mathematician, as, “Eugenics is the study of the agencies under social control that seek to improve or impair the racial qualities of future generations either
physically or mentally” [2]. However, over the 20th century, Eugenics would cause neglect both towards public attitudes, laws, and education for those that were either minorities or disabled. [3] [4] The eugenics movement would also reach outside of the United States, gaining popularity in Europe and Canada. [5] [6], where there would be sterilizations in Alberta, Canada, until the 1970s.

After World War II, many Countries moved away from eugenics, afraid of its association with Nazism. Many public organizations and governments would begin creating laws and bills to help those with disabilities. A few benefits given to the disabled consisted of The Housing Voucher Program and the Americans with Disabilities Act that helped the disabled get comfortable housing in a community setting. [7] Further research on inaccessibility has led to insights into sensory impairments, such as findings made in [8], that showed that space in hallways could cause problems for the visually impaired and disrupt their understanding of where they are in space.

Although there have been numerous attempts at making the world more accessible since the end of the second world war, there are still problems getting effective policies out there to the public. The lack of accessible policies can be due to a lack of applying a social model towards accessibility and a more medicinal ideology towards inclusion [9] being adopted, where the formal understands the need for the impaired feeling included. The lack of clear instructions in paperwork and inflexible deadlines can make participating and staying in different programs hard for those with cognitive disabilities. [7] Also, the lack of measures can be associated with laws not being enforced or not taking effect till the late 20th or even the 21st century, where the Australian Disability Act was not enacted until 1992. [9]

1.2 Recent Developments In Accessibility

In the United States of America, 12.4 percent suffer from some form of disability and as one age becoming impaired becomes more common. [10] The older you get, the more your physical abilities begin to decline, where there are 600 million people who are over the age of 60, making the need for a more accessible world of importance. [11] In this century, visual and
audio accessibility has made many advancements with the help of artificial intelligence (AI), Embedded Systems, and other computer technologies. Recent techniques revolve around technology interpreting data and then supplying information to a different sensory organ; for example, a standard replacement for impaired vision is a PDF reader for the user instead. In the case of auditory accessibility, recent research has shown that using the sense of touch for specific media can be used. By applying pressure to a haptic nerve, the feelings of music in a movie scene are simulated. The same techniques have been used by converting sound in musical performances using vibrotactile armchairs. [12]

Object Character Recognition (OCR) has given computers the ability to recognize characters from a digital image in terms of the visually impaired. For example, OCR can be used to read a paragraph from an image and give insight into tables and graphs that might be hard to read for the visually impaired. The OCR locates tables using a repetitive algorithm that identifies each bar’s size and where it is located on the page using block and line segmentation from a PDF to find the captioning of the blocks. [13] OCR has become common today, where many are open source and are used on multiple OS such as Tesseract and OCRopus. Moreover, towards personal technologies, smartphones, and smart home devices, text to speech, Language Correction, and Predictive Text Suggestion are used with AI Mediated Communication (AI-MC). Examples of text to speech are seen on our phones, such as Apple’s SIRI and Alexa. They read information back to the user and can take orders by command, thus helping those with vision and motor impairments by either receiving outputs or giving inputs. Another useful AI-MC is language Correction and Predictive Text Suggestions; both are included in Apple’s Imessage and can assist users with vision problems, cognitive, or motor impairments. In the United States, over 90 percent of people have integrated using the two mentioned AI technologies; however, with low numbers with elderly where one woman of 60 years said, “since she is older, she finds that the new technologies are too complicated.” giving some worry since most of this technology is beneficial to the elderly. [14] Assistant AI’s have been used often for those with a low vision where the AI use text recognition, object recognition, and face recognition. Examples of Assistant AI in the
market are Supersense, Envision AI, and the LetSeeApp, and all have one of the previously mentioned features. Modern concepts of Assistive AI propose to turn it into an app where the same functions in the previously mentioned AI can be used for all the above and have a chatbot to simulate conversation with the user. It can be used for “better functionality in an app that makes a partially blind user use it for navigation, identification, recognition, and also gaining information of the outer world”, in such means as allowing users to gain information about their surroundings, products, and the world. [15]

The web accessibility guidelines were created in 1999, and they have gone through multiple revisions and cover many disabilities. The guidelines have limits in the combination of disabilities that an individual might have and can therefore limit. It makes it where website design will focus on a generalized crowd of users. Features seen in the guidelines for assistance towards impaired vision are text alternatives, captions, and visual contrast of text. [16] The development of Operating Systems (OS) for the disabled has gained interest, focusing on individual impairments, where the surveys comparing them to non-accessible North American OS have been made. [17] Users were questioned after using both websites through interviews where they were found to be calmer and overall have a better experience when using the Accessible OS. The subjects were tested in two groups, one containing people with disabilities and no disability. [18] Similar to the accessibility guidelines for websites, there is a concern toward specific disabilities, where one user might need more complex requirements than others, and some might need something simple than mainstream OS. Therefore a variable model is proposed for the user-specific product.

Questionnaires are used in a few of the cited papers to test and gain live data on the effectiveness of the guidelines and devices. Evaluations typically use multiple participants with different backgrounds to understand if the device gives the disabled similar performance to users without impairments and how easy the device is to use. The questionnaires after the testing usually contain questions that ask if the end-user is comfortable using the device, how easy the device was to work, and the user's experience using such technology. This procedure gives two things; one is the statistics that the developer gains from the questionnaire. The
other is the qualitative suggestions that the users can give at the end of the questionnaire. Interviews are another method of gaining qualitative data on AT or Accessible Guidelines. The developer finds subjects that fall under a disorder or impairment of interest and then conducts a group interview which can then be followed up by an individual interview later. [19]

1.3 Accessibility Towards Gaming

A big part of life revolves around more than just basic necessity and work; another part is social interaction, as shown in cases of human history and recent records of the prison confinement system. [20] Humans often use a medium for social interaction, where games have lived as one of the most extended living forms of social interactions for the public. Games have been played as far back as remembered, where ancient Native Americans would play dice games, and the term dies or ‘casting of lots’ are used in Jewish, Christian, and Roman texts. The chess game was first seen in India around 500 CE, and Card games were seen as early as the 12th century in China, where many ancient civilizations had some games. [21] Games have also been helpful for learning, where games are often used as learning tools. In general, games in the classroom have been shown to give a motivational component to learning, whereas in learning languages, positive motivation is beneficial for students. [22] Also, games have shown success in teaching students math where it acts as a repetitive device in teaching arithmetic and fractions. [23]

Even though games have existed for a long time, accessibility for games would not be touched until the 2000s, where the lack of accessible games can mean feeling left out or losing important social interaction in one’s life. Many of the developments around this time were the adaptation of the GUI for the disabled [24] [25], improving on guidelines for Universally accessible games [1] [26], and development of methodologies for creating accessible games [27] [28]. Attempts at creating accessible games have seen two models:

• The first was taking an inaccessible game and using AT to make it more accessible.
• The second was to create an accessible game from scratch

both methods have their problems. [1] In the case of the first, there were integration problems with AT devices, as they were not meant for the input/outputs of the games and would need to be adapted, a new version of games means readjusting the technology and does not allow for universal design. The second guideline has issues in marketability and exclusion in that their market for accessible games is low, and the game could cause segregation between able and disabled players. Concerning the latter of these, the marketability problem can be met with corporate social responsibility (CSR), wherein Japan, the attitudes towards this are:

• compliance

• social contribution

• efforts towards sustainability

therefore giving more awareness towards public service. [29] The creation of Human computer Interfaces (HCI) is another massive contribution of this time. Combined with AT can improve the visually impaired at all levels, including a list of customized accounts that could prove helpful to different impairments. [24] [1] In cases of motor impairments, the player may not be able to use the standard controls that a game offers; therefore, AT allow for alternate controls, such as switch controllers or one-handed controllers. Controls become dependent on the type of game the user is playing, as different games will offer different amounts of time to act. To assist players, where one-handed controllers are used, the designer might want to remove certain controls in the game. For example, in a game similar to Frogger, the designer might want to eliminate movement to the left and right as it is unnecessary for victory. [30]

Although recent interest in accessibility to video games has gained insight and intrigue from private companies and academic researchers, accessibility has not been equally looked at by all gaming genres. For example, Collectible Card Games (CCG) have had little to no research to make them more accessible to those with disabilities. A CCG or Trading Card Game (TCG) is a game where a player collects cards from booster packs that have cards of
a different rarity in them, builds a deck with those cards, and then plays a game using cards of that label (card game brand). Most CCG are played with two players; however, some are designed for more. [31] Examples of CCG are the games like "Magic the Gathering", "Pokemon", and "Yugioh", where each game’s cards are similar to a playing card (used in Poker) in size, contains a picture of character or other subject matter, and have card information written on them; card name, card type, special attributes, and stats.

The collection aspect of CCG can be traced back to the Baseball TCG that began in 1904 [32]; although the genre would not be introduced until 1993, this would be considered the first example of it in history. The first official CCG would be Magic the Gathering, which now has a player base of more than 6 million, where CCG’s boast over 10 million players, since 2009, in total. [33] Numerous issues can be addressed towards CCG for accessible guidelines. Some are that players need to hold cards for long periods, communicating with other players may become challenging for hearing impairment. For those with cognitive impairments, memory issues may hinder playing the game. This paper looks at those with low vision to create a proof of concept for bringing over accessible guidelines, where the most significant issue in most CCG for the visually impaired is small text in small spaces.

Many adults begin to lose their sight with age, and since the creation of “Magic the Gathering” the original player base has aged by almost 30 years. Further, CCG can be used as a learning tool as it requires its players to gain skills in “analytical thinking, empathy, social manipulation, iterative design, and communication”, where these skills can be used in other areas of life, making CCG have the potential as a learning tool. Besides these skills, CCG also supplies three key aspects that make it well suited as a teaching tool

- It can be used as an extrinsic motivator to reward students
- In terms of play, the game offers social interaction between players where players will discuss strategy and instruct newer players, and an added part of CCG is the trading of cards where negotiation skills can be built
- CCG involve use of resources, and each card holds different statistics that can be replaced with school material in order to further learning
[34], therefore CCG functions not just as a suitable medium for social interaction but as a learning tool for students. The need to make CCG more accessible is even more crucial as those that suffer from loss of sight can further miss out on a crucial learning tool.

This thesis aims to bring over accessible guidelines adopted for video games and adopts current technology such as AI, microcomputers, and computer modules, to make CCG more accessible. We develop a proof of concept where the main goal is to evaluate if these guidelines were effectively adopted and if AT, such as the one used in the evaluations, can be utilized effectively.

This thesis is organized as follows, the next Chapter 2 goes over the works that this research was based on and used for motivation, where Section 2.1 looks at the guidelines and methods used in accessible video games, Section 2.2 looks at the CCG genre and common traits between and themes in the genre, Section 2.3 goes over the main pieces of hardware that were used in the creation of the AT, and Section 2.4 goes over the software that was utilized in order to recognize the text in the CCG card. The following Chapter 3 goes over the framework of the design for our AT, where Section 3.1 goes over the guidelines that were adopted and adapted for CCG, Section 3.2 goes over the main algorithm for detecting, recognizing, and reading the text to the player, and Section 3.3 goes over the creation of the physical layer of our AT and its interface. Then Chapter 4 goes over the evaluation and testing done during this thesis, where Section 4.1 discusses the methodology used for the evaluations as well as the questionnaire used to gather data, Section 4.2 goes over the data gathered from each of the multiple-choice questions, and Section 4.3 discusses this data and what it means in terms of the guidelines and methods used in the creation of the AT. Finally, the last Section 5 discusses future work and summarizes this thesis. The 5.1 goes over the fixes that will be made to the current algorithm as well as other work that can be done in the future on this AT and for other impairments, and 5.2 summarizes this thesis in concise terms.
Chapter 2

Literature Review

This chapter goes over the literature that inspired this work and helped develop a methodology for the research performed in this thesis. It discusses game accessibility guidelines and accessible technology deployed towards gaming accessibility, interest towards Collectible Card Games, and software and hardware adapted towards creating the AT used in the proof of concept evaluation.

2.1 Game Accessibility

Gamers play games for many factors where two main ones are to have fun and compete. In this case, two things need to be met for full game accessibility:

- Make games accessible to all user groups on release
- The game should be accessible towards all play (cooperative or competitive)

The first ensures that all players can play at the basic skill level. The second implies that a disabled player should be able to play with friends or against another player without their impairment affecting the game’s progression. [1] [30] [24] Thus a big challenge is presented to game designers in that after accessibility guidelines are met, the game must still be a game. Generally, when it comes to the development of video games, several things must be accounted for, such as level progression, input, graphics, sound, and installation and settings.
[25], where for an accessible video game, several of these must be taken into consideration or removed altogether.

In the market, two methods for creating accessible games have been used: creating a game from scratch that uses accessible guidelines or taking a game that already exists and adding accessible technology (AT) to the game. However, the former becomes a market issue where companies will not want to put money into a market with a limited player base. The latter creates numerous problems where the AT may not be compatible with the game, and other hardware issues may occur. [1] Most of the time, guidelines must be used on games on a case-by-case basis as video games come in different genre where first-person shooter (FPS) games are much simpler to make as many use an open-access game engine [30]. Also, games outside the video game market, such as tabletop games, can have unique pieces that have no analog outside of that game. [35] For the visually impaired, this can be the lack of contrast in-game pieces, the unique requirements tabletop games require (aiming, etc), or font size and coloring. In order to find guidelines that are accessible to users and compatible with the game companies design, four criteria are made:

- useful to accessibility consideration
- feasible for game designers
- possible to support game publishers
- economic for game manufacturer

These four must be taken into consideration when utilizing guidelines in-game accessibility.

Guidelines have been suggested by IGDA’s (International Game Developers Association) Special Interest Group (SIG) [26] where they have broken guidelines into numerous lists that can be helpful for game developers at three different levels. The guidelines range can be as simple as contrasting the text and background to providing a pingable sonar map. Even with these guidelines being available to gaming companies, little attention has been shown towards applying accessible guidelines.
The guidelines that were the most consistently ignored were the list features, speed control, and difficulty control, as shown in Figure 2.1. Using high-level design is necessary for giving a comprehensive accessibility breakdown and then followed by applying low-level applications, where some AT might not work with other AT or some game genre’s may need different methods applied. [27]

Over the last two decades, multiple video games have been designed with the idea of accessibility in mind. Two games that attempt to be Universally Accessible (UA) are UA-Chess and Access Invaders. Both games employ multiple accounts to have the best interface for users with different disabilities. [1] [27] The use of screen readers is used for those with low vision in several accessible games where UA-Chess uses this device to provide game information to the player, such as piece position and menu items. Other techniques for helping vision impairments include contrasting objects versus the background, enlarging text, adding a zoom feature, or downgrading the graphics, which have been shown to help low vision and dyslexia cases. How different impairments can affect a game and what part of the game the impairment effect becomes an important factor when solving the inaccessibility. [30] [36]

When playing a game, the player goes through three parts, receive stimuli, determining response, and providing input, where this goes through a repeating loop till the end of the game as shown in Figure 2.2. However, applying only low-level solutions can lead to
several issues, such as solutions that are context reliant. Lower-level fixes can only do so much for those with multiple impairments without understanding high-level guidelines. Console gaming has few peripherals that work well, leading to few gamers with impairments playing them. Players with impairments have been shown to prefer single-player games over multiplayer, both showing a lack of thought being applied towards games in terms of accessibility. [28] When a large number of AT are applied, a matrix can be used to compare AT that get in the way of each other in terms of different guidelines. [27]

Human-Computer Interfaces (HCI) has become necessary in developing accessible games due to them being the source for human interaction in video games. Therefore, the need for an interface that can be accessed by the impaired becomes a necessity for equal opportunity. [25] [24] Two possible Accessible Gaming Interfaces (AGI) are proposed, the first a general interface that allows for play in a large pool of games, and the second a specific interface that can only play a small pool of games. In order to create this, a new Gaming Accessibility Framework is proposed (GAF), where two items are required for such a framework. The first is situational game interactions, and the second is the set requirements for the focused disability. [24]
2.2 Collectible Card Games

When designing a Collectible Card Games (CCG) companies need to consider many things in development, such as rules, intellectual property, cards, and extra items (die, coin, or tokens). There are three parts to the game:

- Collection
- Creation
- Community

where Collecting is what makes the CCG unique amongst other card games. The player collects cards through booster packs or starter packs where the cards they collect can have out and in-game values. The out-of-game value is each card’s rarity, where different CCG have a labeling system for ranking this rarity. The in-game values are the synergy of a card or the overall strength. The creation aspect is where the player combines cards to build a more robust deck. Strong decks usually show a high level of adaptive cards that can synchronize with an extensive range of other cards. The third of these is the community aspect, where bonding with other players through strategy discussions or trading of cards takes place. In retrospect, it has been shown that of these three, the least popular is the Collection aspect, and the most were the deck creation where collecting was enjoyed by 36 percent of players and creating was by 76 percent of players. CCG will have many similarities, such as draw-based system and card-playing requirement, lose/win metric, avatar-related ability, play requirements, rules for engagement, and phase rotation.

The typical CCG is played between two players; however, some can be played with more than one. Often, this could lead to the community making their variation of the game to include more players.

There are also original rules CCG that host a large number of players in them, such as Vampire the Eternal Struggle (VTES), where players must use political and negotiation skills to win, as shown in Figure 2.3. In most cases, turns are symmetric where each player has
the exact chances in each turn, and the turns go back and forth; however, games like “VTES” can be asymmetric. The winning condition can define the game itself, commonly reducing all players’ metrics to zero. Although in some cases, we can see games with numerous win conditions, the most shared being the no more cards in the losing condition or the particular card that ends the game (‘Exodia’ in “Yugioh”). Card movement is very similar between CCG and the movement between areas in the game, deck, hand, in play, and discard pile. As the game goes on, it can hold story elements to add emerging into the game. An example is in “Minionate”, where the game offers storytelling and questing elements where specific card effects will give conditions that must be satisfied to gain a bonus. In addition, cards can bring over conditions from parts of the game.

![Figure 2.3](image)

Figure 2.3: Shows the number of players that participate in a CCG and the flow of play. © 2011 [32]

The cards seen in most CCG have a usual design to them where they will most likely be rectangular and hold unique characteristics at different areas of the card. In addition, the cards can be broken up into different types; for example, the thesis CCG “Minionate” has minion cards and power cards. [31] [37] The cards can have numerous stats amongst them; in the case of the minions in "minionate" they have 1. is the card name, 2. is the card effect, 3. is the attack, 4. is the hit points, 5. is the cost, as shown in Figure 2.4.
Figure 2.4: Shows the a minion card from minionate where the different stats and objects on the card are labeled. The numbers label: 1. The name of card, 2. The effect of the card, 3. attack of the card, 4. Hit points, 5. cost. © 2017 [31]

Cards may belong to an archetype that groups the cards based on either name or belonging to a faction in the game universe. Cards can have numerous labeled effects for similar; this is done in multiple online CCG. In the Cysec CCG, cards are further split into different types of cards as shown in figure 2.5. The differing card effects tell us when the effect is activated, for how long, and the effect range. The card’s ability, which is usually tiny text, can be considered similar to computer code where if the language is not clear, the player is left to interpret as based they can where this can lead to mistakes.

2.3 Physical Parts

The Raspberry Pi (RP) is a microprocessor hooked up to several peripherals, mouse, keyboard, and monitor, where the entire board is printed out. The RP is described as a Single Board Computer (SBC). Ebon Upton developed the board at the University of Cambridge. The intention was to use the board to teach the Python programming language
in schools but was picked up by hobbyists for designing security systems and robotics. [38]

The RP 4B uses a Broadcom BCM2711, quad-core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz processor with memory ranging between 1-8 GB LPDDR4 with on-die ECC. The RP 4B also can connect to the internet having a 2.4 GHz and 5.0 GHz IEEE 802.11b/g/n/ac wireless LAN and holds 40 GPIO pins. The boards OS is imported through SD port on the bottom where the natural Raspbian OS uses UNIX as its base. [39]

A significant asset of the RP is the development of their camera, where the most recently developed one is the HQ camera. The HQ camera offers a resolution of 12 Megapixels and holds a 50 percent higher sensitivity to dim lighting than the RP camera V2. The camera can be combined with numerous C and CS lenses and can also have its back focus changed, giving ranges from 12.5 mm to 22.4mm. The camera can be connected to the RP 4B using the Sony IMX477 sensor, an FPC cable for connection to a Raspberry Pi computer. [40]

2.4 Optical Character Recognition

New technologies such as Neural Networks (NN) have been applied to numerous fields. Since 2010 with the development of deep learning and big data algorithms to support neural networks, this has shown benefits to Object Character Recognition (OCR) and Object Character Detection (OCD) fields. [41]
Standard OCR can detect text but can make assumptions that the image is static and will not detect anomalies. Today OCD makes use of Convolutional Neural Networks (CNN) while not being famous when they were proposed. In the context of document-based text detection versus scene text detection (STD), STD has more challenges to overcome:

- diverse scenery - Text wont always have the same font or color
- Complex background - Can have various objects in the background
- Clarity of capture device - Depending on the device used to take the image there can be numerous differences

where these can lead to uncertain results. [42] The use of CNN was the first scene in 2012 when AlexNet won the Microsoft Image Classification Competition where it made several changes from other such as replacing the sigmoid function with the Relu function, thus reducing cost, using Multiple Graphics Processing Units for model training, and the first use of dropout in order to reduce overfitting were some of the updates to a typical NN. Numerous Deep Learning schemes have been attempted since 2010, where the most recent have developed models based on CNN. A few of these were, Regional-based CNN, Fast Region CNN, and Faster R-CNN, all of which would employ smart region selection strategies to improve accuracy. However, these models would suffer from unorthodox backgrounds and text that had unusual font.

Text detection has numerous characteristics that are notable from other detection problems:

- text sticks to usually a horizontal line
- grammar provides further information
- irregular orientation in some cases(logos, ads)
- multiple layouts and fonts

the first two can be targeted to improve OCD, while the last two can cause issues. In order to get better results for OCD, Segmentation is a powerful tool. Models that use Segmentation
methods would then make a more significant appearance as they would break an image into smaller sub-images which consist of an object of interest and the background as shown in Figure 2.6. [42] The Fully Convolution Network (FCN) would deploy this methodology where it encodes each pixel into a feature map using CNN and then decodes through up-sampling to a prediction map. U-Net performs a similar method where it uses a similar scheme to FCN but forms a symmetry between the encoding and decoding parts, creating more channels and achieving greater accuracy.

Figure 2.6: This shows the process of segmentation used in OCD. © 2021 [42]

The creation of a two-stage pipeline such as East (Efficient and Accurate Scene Text Detector) uses an FCN that skips redundant steps and then sends data through NMS to get the result. [43] Over other STD, this one provides multiple benefits:

- two stages
- flexibility
- speed and accuracy improvements

where the final benefit provides speeds that surpass the current models. A pipeline scheme is used, where multiple channels map the geometry of the image, and one creates a score map. Two shapes are worked with: a quadrangle and a rotated rectangle where the loss function is different for each. The cross-balanced Entropy Function gives the Loss Function for our quadrangle, and the loss is found for the rectangle using the AABB loss in combination with the angle of loss. This model was tested against IC-DAR 2015 and COCO Text, where East showed to be more accurate and faster than either. A few shortcomings to note are that it is limited to vertical and long text lines.

Open CV (Open Computer Vision), a C/C++ library that offers multiple wrappers for other languages, is often used alongside OCR to obtain better results. [44] [45] The typical
usage of this library is for preprocessing methods where the digital image is made more
recognizable to the OCR. The process typically goes through three phases before being put
through OCR: grayscaling, blurring, and thresholding. OpenCV (CV) has a color change
function, called COLORcvt, where the user can choose what format to have the image
converted to and use the function BGR2GRAY as a parameter to output an image with one
channel that only holds the intensity of the pixels. Multiple schemes can be used for blurring
an image, where the purpose is to remove any salt or pepper noise in the background. In
the case of this thesis, we chose to use CV’s ‘FastNLMeanDenoisingColored’ function, where
the function takes in a three-channel image as a parameter. The user specifies integer values
to control the filter strength, rendering for the color filtering, search window for calculating
the weighted average of pixels, and block size for computing weight. [46] The last step is to
use thresholding where a value is chosen, and any pixel value less or greater than that value
is then turned to the max and min values. We use the CV function ‘Adaptivethreshold’,
where it takes a single channeled image as the input and then uses the max value, adaption
method, the threshold type, the blocksize to generate the threshold value, and a constant
subtracted from the mean. We use the adaptive method of 'Gaussian C' and the threshold
type 'Thresh Binary' as parameters. The former uses a Gaussian Window with weighted
constant C being applied, and the latter outputs the max value if the source is greater than
the threshold value or outputs zero. [19] In terms of scene detection, however, there may
be further issues that can arise, such as skewing. Methods that can be added to the ones
above are skew detection and correction and resizing of the image. In low-level solution may
also be to use a high-resolution camera. [45] In the case of high-resolution images, it might
prove helpful to perform blurring where this will make it easier to locate edges for creating
contours around objects. [47]

OCR gained interest around the 1980s, where two current models have gained interest
out of work done. The first of these is Segmentation, and the second is Deep Learning. [42]
Recently, a hybrid methodology combining the two has been utilized where Sequence by
Sequence processing scheme consisting of five parts, image encoding, feature encoding, text
decoding, postprocessing, and model training. The first two stages use CNN and R-CNN to encode the image, the first encoding to a feature map and the second to a latent space. Following this, the third method decodes using another R-CNN where we get Probability Distribution Functions for each possible character. Then these are used to make a decision that is output. The final step outdates the neural network using the last problem for further training.

Pairing the CV library with Tesseract OCR has given good results where this combination gave a 94 percent success rate during testing. [45] However, these same evaluations warn about the low performance towards large text regions where it could take up to 18 seconds to get a result. Further testing has also shown that using these two together while giving good results in the day shows reduced results in bad lighting. [47] The Tesseract OCR engine that excepts binary images as an input and outputs recognized text from that image. It goes through a process of extracting the character outlines and then blobbing the image, followed by organizing the blobs into text lines and analyzing a region, the text is divided between definite and fuzzy spaces. In the final step, the software makes two passes wherein the first it makes an attempt at the name, and the second corrects itself after making adjustments. [48]
Chapter 3

Framework

This chapter covers the high-level guidelines needed when contemplating the design of an AT. We discuss the CCG genre, the items needed in the creation of the AT, how they work and what guidelines need to be considered, the physical setup of the parts and how they connect to each, and a description of the interface.

3.1 Guidelines

As previously discussed in Section 2.1, there have been many guidelines created and work done over the past two decades on developing accessible video games and UA games. [1] [27][30] The development of accessibility for non-electronic games has seen few attempts however where [35] found many issues towards accessibility in the tabletop industry. Likewise, CCG faces many issues concerning accessibility where the cards have small text, gameplay can go on for multiple turns and requires communication throughout the entire game. [34] This thesis focuses on low vision, where the participants had blurring and glaring applied.

High-level guidelines aim to make games still fun and bring a competitive environment. The CCG must still include the collective, creation, and community aspects that make the unique genre while containing the other aspects of available games. [32] [34] A player can assist their friend play, but this takes away from the competitive nature of the game. If the low-visioned player does not have some assistance, the game will not be able to be played
and cease to be fun. Therefore an AT needs to be developed to assist the player, or CCG cards need to be reworked for better accessibility. [1] [24] [30]

The text and font can be hard to read in CCG, where the size is dependent on the amount of information each card must relay. Newer CCG, as shown in Figures 3.1 and 2.4, have attempted to fix this with phrases that generalize redundant text. Using a contrasting and larger font to display important information; however, for older CCG font and text remain an issue. Comparing Figures 2.4 and 3.1 with Figure 3.2, we see that the three most popular CCG don’t make use of the more accessible designs of “Cysec” and “Minionate”. Companies most likely would not invest in massive reprinting or change card design to meet accessibility guidelines. Regarding the cards, in Figure 3.2 we notice that there are five areas of interest as shown in Figure 3.4. Making the comparison between the three cards, we see a similar geometry. The information is spread between three regions of symbols and text where all three have a picture and name in a similar location.

Figure 3.1: Shows card from unofficial learning CCG Cysec where the card shows classical information and formatting that is in older CCG. © 2019 [37]
Figure 3.2: Shows the cards of three most popular CCG. On the Left is ‘Yuioh” card, center “Magic the Gathering” card, and the right is ‘Pokemon” card

About Figure 2.2, we observe that for players with low vision, they cannot collect information from the cards in their hands which breaks the cycle, so they cannot formulate a strategy and then do not know what to play. [30] In areas of the game where cards must remain hidden from your opponents, such as the hand or deck, there is a major problem as the secrecy in these parts is a key attribute of CCG and card games in general. Therefore replacing sight with another sense to relay the information to a player without revealing the cards to the other player becomes necessary. [27] [30] [28]

Also, we must convey the numerous differences between cards to the player in a way that does two things. The first is that the AT must read the card to the player that conveys multiple areas that might not exist or has more information from another CCG. Secondly, there are numerous differences amongst card information even within the card game. For example, in the case of “Yugioh”, as shown in Figure 3.2, there are multiple cards such as monster, spell, and trap, where either one has numerous subtypes, and monsters already have more information than the rest. The first requires us to separate the CCG into independent databases and then create a generalized algorithm that uses the database name to collect and read the different terms unique to each CCG. After this, the card information will be read from the card in question, where a key separator amongst cards in the game will be used to distinguish the card type. For example, in “Yugioh”, the attribute type, a symbol
in information area one, Figure 3.4, where trap and spells have a unique attribute separate from monsters.

### 3.2 Methodology

In designing our AT, we use similar methodologies as shown in [47] [45] where the high level algorithm is shown in figure 3.7a. A digital camera captures the card of interest, as shown in Figure 3.3a,

![Yugioh Card](Image)

(a) Shows the 'Yugioh' card being captured so the player can read the card. The card is called 'Masked Dragon', has attribute fire, monster type is dragon, level is 4 with attack of 1400 and defense of 1100, and information area 2 of Figure 3.4 has its card effect.

(b) Shows the detected words using the STD algorithm of EAST. Once East Detects the name we crop the image so only the detected text is showing for better results.

Figure 3.3: Shows a “Yugioh” card being captured by camera in 3.3a and the same cards name being detected,

, where the card is then located by OCD and recognized by OCR software before being used to search for the card information stored in a database and then outputted to the user as speech.
In order to locate the card, we must choose a unique target for the detection software to locate and then recognize to identify between different cards. Looking at Figure 3.4 we see two standard features amongst popular CCG, where this is the name and the picture of the card, that is found in identical locations on each card. Therefore, we choose the chromatically less complex object, the card’s name, to locate the card. We utilize STD software designed algorithm due to cards having complex backgrounds that can make it difficult for a document text algorithm to localize the name. The OCD we use is EAST as described in Section 2.4 where it utilizes an FCN and has shown promising results versus competing for SDT algorithms, wherein Figure 3.3b shows EAST detecting the words of Figure 3.3a. [43] Once the text is located on the playing card, characters still need to be understood by the computer, so the use of OCR is needed. We use the python wrapper of Tesseract to obtain the characters that are located from EAST.

![Figure 3.4: Shows the typical structure of a CCG playing card. The main geometry consists of three areas to store information through text or symbols, and then two card verification areas where one is the card name and the other the picture.](image)

Going straight from detection to recognition will not give perfect results. However, due to artifacts, salt and pepper noise, and the OCR limitation, prepossessing and filtering after the recognition is necessary for a good final result. [44] This new methodology adds onto the preprocessing methods that are utilized in [47] [45] alongside Tesseract. We denoise the colored image to get rid of the salt and pepper noise and then reduce the channels of pixels
to just the intensity, shown in Figure 3.6.

(a) Shows the filtering method being applied to Figure 3.3b where the Colored denoising is used in CV as described in Section 2.4 with filtering parameters of 8, window size of 7, and block size of 21.

(b) Shows the grayscaling of Figure 3.5a where we use the cvtCOLOR function described in Section 2.4 using BGR2GRAY as the color space conversion.

Figure 3.5: Shows the filtering and grayscaling of Figure 3.3a

Another problem for the text is that not all CCG cards have black text names, as shown in Figure 3.6a, where Tesseract has problems detecting non-black text (it can detect white but has lower performance).
(a) Shows a trap card from the game “Yugioh”, where the object of interest is the white text at the top of the card.

(b) Shows not operation performed on Figure 3.6a using the bitwise function of CV

Figure 3.6: Shows a “Yugioh” trap card containing white text for its name in Figure 3.6a and in Figure 3.6b we show the name of the same card after being put through a not function.

We use CV’s bitwise function to perform a not operation on the image’s pixels, as shown in Figure 3.6b, where the white image text becomes black.
(a) Shows basic algorithm used to capture image, locate text, recognize text, retrieve data, and then output key information to player.

(b) Shows the process Card Reader algorithm with added steps to help recognition and increase search results for database.

Figure 3.7: Shows the process of the card being read, where the card is captured, detected, recognized, searched, and then read to the player in Figure 3.7a, and Figure 3.7b adds a preprocessing method before Recognition and filtering before searching.

We continue the process used in [44] [47] [45] where we apply thresholding to get a binarized, as shown in Figure 3.8.
(a) Shows thresholding being applied to Figure 3.5b

(b) Shows thresholding being applied to Figure 3.6b

Figure 3.8: Applies thresholding using CV’s adaptive threshold function as described in Section 2.4 where we use a block size of 11 and constant of 2.

Following the OCR the characters are outputted to a python dictionary datatype, where we then begin to filter the findings as shown in Figure 3.10.

Figure 3.9: Shows the characters that are recognized by the Tesseract OCR, followed by unacceptable characters being filtered out, then a string of the characters of each word being created to be put into a temporary list to be compared to an acceptable word, once acceptable word is found is added to a string, where the final name is used in a query to find the record of the card that is stored in a tuple data type.

The first filtering process eliminates any unnecessary characters picked up by the OCR, where this contains any character not in the English Alphabet. After this, we match the
words produced from Tesseract to the words found in our database, where if they match with an acceptable word, they are saved, as shown in Figure 3.7b. If the name doesn’t match anything in the database the word will be deleted and the algorithm will start over at the preprocessing stage. After every six fails, the parameters for filtering are incremented in the denoising function, and the adaptive thresholding blocksize and C values are also incremented; the whole algorithm is shown in Figure 3.10. We use this ‘adaptive preprocessing’ due to observations that the preprocessing methods would give different results depending on cards and the environment that they were played in typically due to lighting. [45] The output of the OCR and the different stages of filtering can be observed in Figure 3.9, where it begins with the recognized words and ends with the output of the database record.

Once the information is put inside the tuple, we replace this information into a python dictionary data type. The dictionary’s keys will depend on the database being used at the time. We then read this dictionary through a for loop using the Espeak text to speech software to read the dictionary to the user.

![Image](image.png)

(a) Part 1 of algorithm

(b) Part 2 of algorithm

Figure 3.10: shows the filtering algorithm used in full.

### 3.3 Setup

The physical setup of the device consists of the RP 4B, RP Touchscreen 7 inch Monitor, RP HQ camera, and a 3d printed microscope, as described in Section 2.3. We construct the microscope base from three parts: a base, stand, and holster. These three parts are
assembled where the stand is placed into the base and the holster is then placed into the stand as shown in Figure 3.11. The card is placed on the microscope’s base for capturing. The camera is held by the holster over the base and awaits for the command from the user. The HQ camera lens is 12mm focus length, so the stand is measured for the lens where the camera is placed through a hole at the top of the holster and is held down by a lid or rubber bands.

![Figure 3.11: Shows the microscope stand for the HQ camera and the base where the card is placed for capturing.](image)

The RP 4B is attached to the HQ camera through an FPC cable. The RP 4B is attached to the back of the monitor, where the monitor is screwed. The RP 4B and the camera are attached, so the microscope and the monitor must be close. The device can be operated using a touch screen or keyboard set up.

![Figure 3.12: Shows the connections of the monitor to the RP 4B SBC.](image)

The Graphical User Interface(GUI) is set up following the advice given by [26] [24] [25]
where we attempt to keep the interface as simple and easy to understand for those with low vision. We make our GUI have contrasting colored buttons from the background where the background is white, so we have black buttons with the white font to make them clear to the user. The font is made prominent for the user to read what the words read as well. Using the monitor, the user can press the button on the screen to use the device, where the monitor will show the camera’s frame in a continuous loop. The loop is broken by pressing the s key on the keyboard twice, where the image will then be captured and sent through the algorithm. It takes between three to five seconds for the STD to locate the name. In the final version, a scroll-down menu will be given so the player can choose the database they wish to use, where this is all shown in Figure 3.13.

Figure 3.13: Shows the proof of concept for the GUI where there is a main button where it contrasts with the background as well as has its own font contrast with it. The font is all bold and large to make it more recognizable and the GUI provides a scroll button.
Chapter 4

Evaluation Results

In this section, we go over the evaluation procedure used, the data collected from the evaluations, and discuss the data in comparison to suggestions made and what was expected from the high-level guidelines.

4.1 Evaluation Process

In order to test our framework, we designed a proof of concept and performed several evaluations, where participants played a CCG against the author of this thesis. These evaluations would be used to see if the player quickly understood the device, if the device was flexible enough, and if the device interfered with the game’s fun.

The process of the evaluations began with participants being given a demonstration of the device, where the participant wears glasses to simulate the vision of someone with low vision. Following this, the participant tries a few cards until they think they understand how the device works, and then under the same conditions, they play a CCG with this author. We integrated a game of “Yugioh” into the evaluation, where the rules are altered to make the game move faster. The altered rules are limiting the number of cards in hand, the number of cards on the field, the sizes of the decks, and adding rules that target when the participant could leave the game.

Before the game began, all rules were explained to the participant, and we broke this
explanation down into three parts, card types, game mechanics, and the game objective. The first explained the three cards types and their differences, the second was how to play the different card types, and the third was how to win the game. This gives each player a basic understanding of game rules, so even novices can test the AT.

After finishing the evaluation, the participant answered a quick survey that consisted of ten questions. Ten of the questions were multiple-choice, and one was a short answer question that asked for suggestions for future work. The first ten questions can be broken into three types:

- Questions about participants understanding of AT interface
- Questions about the AT concerning the game
- Questions about the participant’s enjoyment of the game concerning the AT

The first characterizes questions 1-4, the second questions 5, 6, and 8, and the last questions 7, 9, and 10.

4.2 Survey List

In these evaluations we tested 51 participants where after the game all completed the questionnaire that consisted of 11 questions:

- Question 1: How was the simplicity of the device?
- Question 2: How easy was the system to use?
- Question 3: How comfortable was the interface of the device?
- Question 4: How difficult was the device to learn?
- Question 5: When a mistake was made could you recover quickly?
- Question 6: How helpful was the device in playing the CCG?
- Question 7: Did the device take away from the enjoyment of playing a CCG?
• Question 8: Were you aware of the different cards in your hand?

• Question 9: What is your familiarity with the CCG genre?

• Question 10: Would you suggest a device similar to this one for playing CCG?

• Question 11: What are some improvements and suggestions you would make for this device?

, where these are the ten multiple choice questions and the last question is short answer.

4.2.1 Question 1

Figure 4.1: Shows Figure 4.1 with bin 1 of 0 percent, bin 2 of 2 percent, bin 3 has 20 percent, bin 4 with 50 percent, and 28 percent. The average was 4.039 with a standard variation of 0.747. This is question 1: How was the simplicity of the device?

This question asks how simple was the AT’s interface to understand, where we are looking to see if the system is too complicated for someone with low vision to figure out. Looking
at Figure 4.1 we see that the majority of participants for this question gave us a rating of three or higher. A rating of one is the device was incredibly complex, two was the device was complex, three was the device was okay, four was the device was simple, and five was the device incredibly was simple. Out of 53 participants, over 70 percent gave us a rating of four or higher, where the mean was 4.039 with a standard deviation of 0.747. These statistics show that the device was simple to use for those who had their vision impaired and shows that a large button with the contrasting font for the operation works well for users with impaired vision.

4.2.2 Question 2

![Histogram for Q2: How easy was the device to use?](image)

Figure 4.2: Shows Figure 4.2 with bin 1 of 0 percent, bin 2 of 2 percent, bin 3 has 14 percent, bin 4 with 62 percent, and 22 percent. The average was 4.039 with a standard variation of 0.682. This is question2: How easy was the device to use?

The second question asked the participant about the ease of the device, where we were interested in what they thought the ease of operating the device was. Looking at Figure 4.2,
we see that over 60 percent of participants gave the system a rating of four, where a rating of one was the device was extremely hard to use, two was the system was hard to use, three was the system was okay, four was the system was easy to use, and five was the system was straightforward to use. The mean of our ratings was 4.039, with a standard deviation of 0.662. These statistics show that most of the participants thought that the system was okay, easy, or straightforward to use; over 90 percent of participants show that most participants were able to operate the AT with low vision efficiently.

4.2.3 Question 3

![Histogram of Q3: How comfortable was the interface of the device?](image)

**Mean = 3.078**  
**Std dev = 1.246**

Figure 4.3: Shows Figure 4.3 with bin 1 of 8 percent, bin 2 of 26 percent, bin 3 has 36 percent, bin 4 with 8 percent, and 22 percent. The average was 3.078 with a standard variation of 1.246. This is question3: How comfortable was the interface of the device?

This question aimed at seeing how the participant thought of the read information, whether the information was understandable, and if the text to speech was legible to the participant. Looking at Figure 4.3 we see an average of 3.076 with a standard deviation
of 1.246. A rating of one showed the device was uncomfortable, a two was the device was slightly uncomfortable, a three was the device was moderately comfortable, four was the device was slightly comfortable, and a rating of five was the device was comfortable. Here we see that the two highest bins are a rating of three and two, making up over 50 percent of participants. These statistics mean that our device’s output was uncomfortable for the participants to understand and that the text to speech was robotic.

4.2.4 Question 4

![Graph showing distribution of ratings for question 4](image)

Figure 4.4: Shows Figure 4.4 with bin 1 of 0 percent, bin 2 of 0 percent, bin 3 has 6.1 percent, bin 4 with 69.4 percent, and 24.5 percent. The average was 4.180 with a standard variation of 0.523. This is question 4: How difficult was the device to learn?

In this question, we are looking to see how difficult the device was to learn, meaning we are interested in if it took the participant a long time to get used to the controls of our device. The rating of one was that our device was difficult to learn, two was the device was slightly difficult to learn, three was the device was bearable to learn, a four was the device was slightly easy to learn, and a five was the device was easy to learn. Taking a look at
Figure 4.4 we see that over 90 percent of participants thought that the device was slightly easy to learn to the device easy to learn, where the average is 4.160 with a standard deviation of 0.523. These statistics show that the device has a quick learning curve, whereas for an AT, this is ideal, as we want the user to use the device without a significant time spent learning the controls.

### 4.2.5 Question 5

![Histogram showing the distribution of responses to Question 5](image)

Figure 4.5: Shows Figure 4.5 with bin 1 of 0 percent, bin 2 of 4.2 percent, bin 3 has 8.3 percent, bin 4 with 64.6 percent, and 22.9 percent. The average was 4.041 with a standard variation of 0.786. This is question 5: When a mistake was made could you recover quickly?

This question looks to see how a participant was affected when a mistake was made and if the mistake frequently occurred when using the device, where a rating of one meant it was hard to recover once a mistake was made, rating of two meant the device was slightly hard to recover, three was the device was slightly easy to recover, a four was the device was easy to recover when a mistake occurred, and a rating of five was where the player never made a
mistake. Looking at Figure 4.5 we see in the range of the device being slightly easy to recover from to easy to recover from over 70 percent of participants agreed, where over 20 percent of participants never had a mistake occur. The average for this question was 4.041 with a standard deviation of 0.706 were showed that most participants either recovered quickly or never made a mistake. The statistics showed that the setup of the AT is simple enough where mistakes are rare and straightforward to fix.

4.2.6 Question 6

![Histogram of Question 6](image)

Figure 4.6: Shows Figure 4.6 with bin 1 of 0 percent, bin 2 of 6 percent, bin 3 has 20 percent, bin 4 with 52 percent, and 22 percent. The average was 3.882 with a standard variation of 0.816. This is question 6: How useful was the device in helping to play the CCG?

This question asks if the device was helpful in playing card games, where we are looking to see if the device was helpful to a player whose vision is impaired. Looking at Figure 4.6 we see that over 70 percent of participants agreed on a rating of 4 to 5, where a rating of one was the device was not useful, rating of two was the device was slightly not useful, a
rating of three was the device was moderately useful, a rating of four was the device was slightly useful, and a rating of five was the device was useful. Overall less than 10 percent of participants found the device in a range of not useful to slightly not useful, where the average was 4.041 with a standard deviation of 0.706. These statistics show that the device serves its primary purpose of helping impaired individuals play CCGs.

4.2.7 Question 7

![Bar chart showing the distribution of responses to Question 7](image)

Figure 4.7: Shows Figure 4.7 with bin 1 of 2 percent, bin 2 of 4 percent, bin 3 has 21.2 percent, bin 4 with 22 percent, and 54 percent. The average was 4.196 with a standard variation of 1.020. This is question7: Did the device take away from the enjoyment of playing a CCG?

This question asked if students thought the AT made the game less enjoyable, where the accessible guidelines should not take away from the game’s fun. Looking at Figure 4.7 we see that over 70 percent of participants gave this question a rating of 4 or higher, where a rating of one was the AT made the game not fun, a two was the device made slightly enjoyable, three was the game was okay, four was the game was slightly enjoyable, and a five was the
game was still enjoyable. In this question, most participants thought the game was still fun while using the AT where the average was a 4.196 with a standard deviation of 1.820, where the high standard deviation was caused by one participant saying the game was made to be not enjoyable. Overall, we see many participants saying the game was still enjoyable, where the game being unaffected by the AT is the most common rating. These statistics showed as a high-level guideline in-game accessibility says that the AT cannot take away from the game’s fun.

4.2.8 Question 8

![Figure 4.8: Shows Figure with bin 1 of 2 percent, bin 2 of 18 percent, bin 3 has 12 percent, bin 4 with 44 percent, and 24 percent. The average was 3.706 with a standard variation of 1.082. This is question 8: Were you aware of the different cards in your hand?](image)

In this question, we ask if the participants knew the identity of the different cards in their hands after reading. We are looking to see if the AT supplies concise instructions to the player about the card being read. Looking at Figure 4.8 we see that over 60 percent
of participants gave a rating of 4 or higher. A rating of one was you do not know any of your cards, a two have a little understanding of what a few of your cards do, a three was you know some your cards fully, a four was you knew most of your cards but not all, and a five was you knew all of your cards. We see a higher standard deviation of 1.082 for this question. A larger group of participants gives a rating of having a little understanding of what a few of your cards do, where the average is 3.706. We see a large portion of participants understood what the majority of their cards did, but there is still over 30 percent who did not know what their cards were or had only a vague understanding of their cards and the card’s statistics. These statistics are concerning as the AT needs to give instructions that the player understands.

4.2.9 Question 9

Figure 4.9: Shows Figure 4.9 with bin 1 of 6 percent, bin 2 of 42 percent, bin 3 has 38 percent, bin 4 has 8 percent, and bin 5 6 percent. The average was 2.667 with a standard variation of 0.931. This is question 9: What is your familiarity with the CCG genre?
In this question, we ask about the participant’s familiarity with the CCG genre. We want to know how much of the participants rely on experience when using the AT. Looking at Figure 4.9 we see that over 80 percent of participants gave a rating between 1 to 3. A one was they never heard of a CCG, a two was they heard of them but have never played, a three was they have played a little in the past, a four was they play every once in a while, and a five was they played all the time. We see an average here of 2.667 with a standard deviation of 0.931, where we see that most participants had some idea of what a CCG was or had played them in the past, giving us a majority of novice players. This result is good as it shows that our device was helpful to players that already had little to no knowledge of their cards or the game.

4.2.10 Question 10

Figure 4.10: Shows Figure 4.10 with bin 1 of 0 percent, bin 2 of 2 percent, bin 3 has 20 percent, bin 4 has 40 percent, and bin 5 38 percent. The average was 4.118 with a standard variation of 0.816. This is question10: Would you suggest a device like this to someone for playing CCG?
This question asks if the participant would recommend the AT to someone they know, where we want to see what the participant thought overall and if they would recommend it to someone with low vision. Looking at Figure 4.10 we see that a over 70 percent of participants gave this question a rating of four or higher. A rating of one was they would not recommend, a rating of two was they probably would not, a rating of three was a maybe, a rating of four was the probably would, and a rating of five was definitely would. Overall, the participants said they would recommend the AT, where the average was a 4.118 with a standard deviation of 0.818. These statistics showed that the participants thought the AT was beneficial to playing CCG.

4.3 Discussion

In terms of usability, most players found the AT was simple and easy to operate, as discussed in Sections 4.2.1, 4.2.2, and 4.2.4. The ease of using an AT is essential for those with impaired vision as a more complex setup can be disorienting and hard to learn. In many cases, they would have some level of assistance [28] however, the player should be able to understand where buttons are in the GUI and what phase of the program the device is processing. Further, the learning curve should be low enough to get used to the interface as fast as possible.

The main concerns that appeared during evaluations were the comfortability of the interface. Where if the participants could recognize the difference between the cards in their hands after being read. In Section 4.2.3 we see the percentage of students that thought the device was uncomfortable and moderately comfortable being in the majority. Using the suggestions from question 11, we see that this was due to two factors, the first being that the speech to text is hard to understand, and the second is that the lack of a cardholder on the base of the microscope, as shown in Section 3.3. Both of these factors can cause problems to competitive play and friendly play of CCG [27] [30]. As in the case of a card not being easy to read, it could slow down the game’s play. In the case of the placement of the card, this can lead to bad reads, as described in Section 2.4 The text problem can be solved by
purchasing a better text to speech where the voice sounds natural however, in the case of the card holder there two methods that can be considered such as adding a card holding area on the microscope and adding skewing algorithms that detect and correct the angles. Looking at Section 4.2.8 while we see less conflict, we still have a more significant variation compared to the other questions as participants had a hard time keeping track of the cards in their hands. As the point of the AT is to make up for lack of information due to poor sight, Figure 2.2 and if players cannot recall what was read, this can lead to further problems. Therefore adopting methods used for memory impairments, such as ones used in UA-Chess [1], where a list on the screen can be used for keeping track of cards that have been played. If a player wishes to have the card reread, they can tap on the card’s name in the list, where it will be read without needing to be captured again. Similar methods were suggested for quick access of past cards where the last five cards would be saved for further quick access. Even with these two major problems, the majority of participants thought that the AT was moderate to incredibly useful for playing CCG as shown in figure 4.6.
Chapter 5

Conclusion

In this section, we discuss the future of this research, where this consists of improving the algorithm and the interface and discussing possible guidelines for other impairments, and we summarize this thesis.

5.1 Future Work

The future work of this thesis will revolve around three parts:

- Improve algorithm
- Improve interface
- Incorporating guidelines for other disabilities

We hope to develop AT that can help with a variety of disabilities and help develop guidelines that can help a larger population of CCG players.

Our proof of concept shows that many of the guidelines that worked well for video games work well for CCG; however, while our proof of concept was well received, several improvements can be made for further accessibility. In further developing an algorithm that makes full use of the unique characteristics of different CCGs, it is necessary to improve the speed and efficiency of reading the card successfully. The first of these would be using the
CV software, mentioned in section 2.4, to locate and recognize the color of the pixels of the CCG cards.

Observing the cards in Figures 3.3a and 3.6a we see the cards come in different colors, where different card types are often color schemed in CCG. We can use this color coordination in CCG to figure out a crucial part of information before recognizing the card’s name. In the case of “Yugioh”, this can be used to differentiate between a monster card without an effect, a monster card with an effect, spell, or trap card where each card has different pieces of information necessary to play. One method of using this information is to separate the different acceptable words into three different lists differentiated by the card type making it easier for card recognition. In other CCG this can prove helpful as well, for example in “Pokemon” the color of the card can represent the element of the card where red is fire, green is grass, and blue is water.

The current filtering algorithm currently in use, see figures 3.7b 3.10 and 3.7a, where this algorithm has proven to be inefficient and unreliable, where the inefficiency comes from the searching process having to go through each word, and requiring an exact match of a word for it to be accepted, and the unreliability is partially due to the poor angles of the card. In order to fix this, two additions are proposed, the first is mentioned in [47] and shortly mentioned in section 2.4, where the use of skew detection and correction would help. Most failed card reads were due to the angle of the card, confusing the text recognition software. Adding skewing after the OCD, where we resize the image to include only the detected text, can help increase the success rate.

We can further improve the algorithm by changing the filtering process where two parts would be added to our current algorithm. The first is using a point system to replace the recognized word with the closest match, where the recognized word is compared to a list of acceptable words where each recognized word is given a score of the matching characters of that word. The highest scored word replaces the recognized word and then moves on to the next word for comparison.

In order to speed this process, we adopt a searching algorithm where it does not need
to search through every card in the database. We look into using a Binary Search Tree algorithm, which uses a median 'root' word that is the first word that will be compared to the OCR-generated word. If it matches the root, the generated word will be changed to the matching word, but if there is no match will move to the left or the right depending on if the generated word was less than or greater than the root. After this, it goes to a new word used in the database. Once again, no match will go left or right to the next group of words until a match is found. This Binary Search Tree would speed up the matching of a legitimate card name as each time a node is compared to the input word, if there is no match, it will divide the number of words that it searches through dividing the number of words by \( n/2 \) where \( n \) is the number of possible words. This new algorithm uses color matching to slim down the number of cards that the algorithm needs to search. After this the recognized name will be fed into the search tree. If no match was found, the algorithm will select the word with the highest number of matching characters. This would improve the current algorithm by improving the rate of success and increasing the time on each search.

The next phase would be to improve the current interface to be user-friendly and get rid of current flaws and limitations. Things that did not get finished for the proof of concept were adding multiple databases that could be referenced. In this case, a user would use a scroll-down menu, as shown in Section 3.3, where they would use it to select a string. That string would then be used in two parts; the first is to change the database to the python connector is connected. The second is to change the number of variables and dictionary keys used to read the card information to the user, as shown in Section 3.2.

The suggestions that were mentioned in Section 4.3, are taken under consideration, where the two biggest concerns are improving the comfort and the coherency of the cards. Adopting more life-like text-to-speech reader will lead to a better response from users where the speech is more transparent and easier to understand. A suitable replacement for text to speech would be Amazon Polly as it offers numerous voices and can be customized for the user’s preference. Another need is to help users identify cards in their hands and simplify the information read. Cards could be placed into a dictionary data type, where every time a card is read in the text.
to speech, the card information gets stored into a dictionary. When the next card is read, it pushes it over to a different dictionary data type. The new information is then accepted into the data type previously holding the prior information. This would act similar to a shift register where information is moved for new information as more information is read. Further card information needs to be adapted to be read individually stored information. The card information can be read by changing how information is read into the text-to-speech engine.

In terms of refining guidelines, we refer to guidelines previously used in developing UA video games [26]. The main feature that will need to be added to our design is for the interface to be user-adjustable, where the user can adjust the font and interface size using a menu. A flexible interface will help those with worse vision than others to see the buttons. A major change from the current button interface is adding speech recognition software for the user to speak a unique command, to activate the speech recognition, followed by an order for the system to perform. The first would be used to activate the voice recognition, while the second could be used to give further commands, so adding more buttons to the GUI would not be necessary; this is similar to how apple users tell Siri a command. The orders would allow for complex instructions to be given; for example, 'read card 5' would allow for the fifth card read to be repeated in full to the player, or a more complex command being, 'read attribute of card 5', would read a cards attribute to the player.

Further research of guidelines on other impairments is also possible for the future. Developing a device that caters to multiple disabilities is desirable, where guidelines for those with hearing, motor, and cognitive impairments would be the focus. In the case of hearing impairments, these do not impair players of CCG as much as others, but adopting guidelines can help those with dual impairments. In case of poor hearing adding large caption font on the screen as the text is read can help those hard of hearing with low vision. Combining this with having an option to slow down the text to speech for easier comprehension could also prove useful.

In terms of cognitive and motor disabilities, these two impairments can affect players of a CCG differently than hearing and vision impairments, as shown in Figure 2.2. In the latter’s
case, they interrupt the player’s ability to receive data to act on, while cognitive disabilities prevent players from creating a strategy to employ. In the case of motor impairments, the player cannot output the correct solution. For players that suffer from short-term memory, a list that appears on the interface that contains the names of cards that were recently played could be held. For those with memory issues and impaired vision, the cards that are read for the text to speech can be added to this list for those with short term memory. In the case of the motored impaired, there may be a need for the cards to be held for them and help drawing cards where new AT can be created for assistance.

5.2 Summary

This thesis aimed at bringing guidelines that were once used in developing accessible video games over to helping to make CCG more accessible. In order to prove that these guidelines work on a lower-level, a proof of concept was made. An AT that could help those with low vision was created. The concern for game accessibility becomes a major concerns for two key reasons, the first is that gaming serves as a medium for social interaction and can lead to new friendships being formed. The second is that games have shown to be great learning tools; as described in Section 1.3, individuals that have disabilities should not be denied these opportunities and experiences. The CCG genre has seen considerable growth over the last decade, yet no real research has been proposed to bring guidelines over to the genre.

Usually, in video game accessibility, two methods are used, create an AT to make a game more accessible or develop a game that is already accessible on release. Due to having thousands of cards in rotation, CCG will most likely never adopt the latter method as that would require massive reprinting of cards, which leads to creating low-level AT to make the genre more accessible. In order to prove that such an AT is possible, we make a proof of concept that will support a low vision user in playing a CCG. In the making this AT, we adopt an RPI-4B where the SBC acts as a small computer that can be outfitted with a digital RP HQ camera. Using the size of the RPI-4B and its interface, we adopt software for text
detection, recognition, and text to speech methods to read the player’s card information.

In the design for a low-level AT we refer to high-level guidelines that have been used in prior video game accessibility creation. Most of these go into the design of an interface with a bold font that is large and easy to read and buttons with similar attributes. A methodology for applying these practices is taken up where we use the cycle shown in Figure 2.2 where we see how this process is disrupted for low vision players. In order to replace data that would be given to vision in games, replacing this with another sense becomes the primary solution where replacing sight with hearing is expected. In order to incorporate these methods towards CCG we must acknowledge the unique characteristics of CCG on a high and low level. At the high-level, the CCG has three characteristics that stand out, Collection, Creation, and Community. We must provide accessibility without taking away from these three aspects when applying guidelines. At the low level we must respect the unique characteristics of the cards, where many CCG have different types of cards with different statistics as shown in Figure 3.2. We make use of the similar characteristics of the CCG layout shown in Figure 3.4 where we utilize the similar location of the name to use in a database query that records the statistics in that record and reads it back to the player. We design a physical layer similar to a microscope so that the player can place a card underneath the camera and control the camera through a GUI button as shown in Figures 3.11, and 3.12.

We then perform a series of evaluations to test our proof of concept where we adopt a questionnaire used to develop UA video games [1]. The evaluation consists of playing Yugioh the CCG with this author followed by answering a questionnaire where questions are split into three types as described in Section 4.1. The data from the questions was generally good where on a rating system of 1 to 5 the majority of averages were above four and the standard deviation was below one. However, key things to be aware of were the understanding of the cards in the participants’ hands and making the interface more comfortable for users. In future work, we attempt to correct these problems and add numerous features to improve the interface of the AT and increase its performance.
Bibliography


[16] [Online]. Available: https://www.w3.org/TR/WCAG20/.


