Exploration of Augmented Reality as an Assistive Device for Students with Dyslexia

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We pledge on our honor that we have not given or received any unauthorized assistance on this assignment.

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Abstract

Individuals with learning disabilities drop out of school at a rate twice that of their general education peers. Dyslexia, a disorder which affects one's ability to read and write, is among the most common of these learning disabilities. Team ART aims to explore the use of augmented reality (AR), as an assistive device platform for people with dyslexia. Team ART will first survey the dyslexic community to determine the most helpful features and user interface for an application which both manipulates documents to make them more readable and provides real time handwriting correction for people with dyslexia. After the development phase is complete, Team ART will perform controlled tests to determine the efficacy of the application in improving the dyslexic population's reading and writing abilities.

Chapter 1: Introduction

Although the augmented reality(AR) industry focuses an ample amount of energy into the gaming sector [1], describing the versatile technology as merely a gaming platform does it an immense injustice. AR enables users to experience the real world alongside virtual images or information which are superimposed onto the actual environment [2]. The ability to alter and enhance humans' perception of the world has applications far beyond entertainment. Industry leading companies such as Google, Amazon, Apple, Facebook, and Microsoft have already taken a stake in AR development. Team ART aims to help realize this technology's potential by developing an AR application to improve human lives.

In particular, Team ART plans to take advantage of AR to assist individuals with dyslexia by creating a program that corrects handwriting in real time. In order to implement the specific application, the team has researched preexisting code and algorithms to help identify handwriting as well as aid in correction. Once the methods have been analyzed to determine the feasibility of this application, the team intends to compare different AR devices to find the best overall platform to use.

Chapter 2: Literature Review

2.1 Background on Dyslexia

About one in five people have a language-based disability, the most common of which is dyslexia, which is characterized by difficulty in decoding reading, spelling, and recognizing words [3, 4]. Learning disorders can damage the livelihoods of many in the world, since two out of three non-readers withdraw from high school and thus cannot receive higher education making it difficult to become successful in life.[4]. Any method that can be developed to help alleviate the symptoms of dyslexia or allow people with dyslexia to better function in their daily lives would help to aid many people in the world. Since most treatments for dyslexia use educational tools to help enhance reading [5], the use of augmented reality as a similar tool or aid could benefit the affected population.

2.2 Application - Live Handwriting Correction for Dyslexia

AR could further enhance the quality of communication for people with dyslexia by helping them learn how to write more accurately. The team's concept features an AR headset worn by a user that tracks the words that the user writes onto paper. If there is a misplaced or invalid character, the headset would highlight that character, predict what the user wanted to write, and help them correct the mistake, allowing them to better identify weaknesses and creating immediate feedback.

Previous research has been done on handwriting correction and pattern/letter recognition, but there little to no public information regarding the implementation of combining the two methods on one AR headset. Commercial devices such as the PalmPilot, DragonDictate, and Apple MessagePad [6] provide potentially comparable service;. however, these products only detect syntax/spelling errors - not invalid characters that some dyslexics frequently write. Another shortcoming of these products is that they only analyze handwriting after the user has finished an entire sentence. Team ART would like to explore finding a way to make corrections live while the user is writing.

Most research done on live handwriting detection proposes a multimodal interaction mechanism where a device first allows the user to write on a tablet-like interface, and synchronous speech is used to give correct characters [7]. This combination of written and verbal verification helps to increase the accuracy of the correction algorithms. However, the use of speech input introduces errors due to ambient noise or other outside factors, and reduces ease of use for the device [8]. For these reasons, Team ART aims to find a solution that works solely with handwriting and does not need to be provided verbal confirmation to fix syntax/spelling errors. Recovering speech recognition errors would require correction at specific steps during the process. Handwriting, however, is slow but reliable. It eliminates many of the outside factors associated with speech such as extraneous noise and information, making it an ideal mode of input for error correction purposes.

When identifying errors in writing, there are currently two different methods[8]. One method breaks down handwriting into words and attempt to edit or predict entire words in the interest of efficiency, doing less work. Other systems break down sentences into words and individual characters with the hopes of making predictions more accurate by analyzing words at the character-level. Research done on character-level analysis of handwriting will be very helpful because people with dyslexia will most likely make more errors with specific characters rather than whole words.

2.3 Algorithms

In order to properly assist individuals with dyslexia, the AR device must first be able to identify letters and interpret handwriting. Many image processing algorithms used as a means to this end rely on machine learning techniques to allow computers to process incoming information. The following sections will give an overview of machine learning techniques, followed by a description of image processing algorithms relevant to the creation of an AR device for people with dyslexia.

2.3a Machine Learning and Neural Networks

A fundamental task in using technology to assist humans is the identification and exploitation of different patterns. Thus, the use of machine learning - which automates the acquisition, organization, and gaining of skills from information - is essential for producing assistive systems [9]. In general, machine learning discovers and uses statistical regularities in existing training data in order to improve performance on a task. Over the past several years, different paradigms of machine learning have been used for different tasks. These include case-based algorithms, which represent knowledge as specific cases and retrieve these cases to apply them to new situations, genetic algorithms, which iteratively generate rules to describe a situation based on the fitness of parent rules, and rule induction algorithms, which use decision trees or other knowledge structures to select attributes of the data for incorporation into the knowledge structure [10]. Machine learning researchers also use artificial neural networks, which are modeled after the cellular structure of brains, to analyze patterns in data [11].

Artificial neural networks (ANNs) have emerged as one of the leading techniques in modern machine learning. Feed-forward neural networks, the most widely-used variety of ANNs, operate by sending data through layers of nodes, where each node processes its inputs and passes the processed data onto nodes in the next layer [11]. These networks are often composed of three types of layers: an input layer, which brings data from an external source into the network; an output layer, which classifies the processed data for human comprehension; and a number of hidden layers, which appear between the input and output layers and serve to extract features from the data.

Every node in a given ANN relies on a set of arbitrary parameters which can be chosen to optimize the ANN's behavior for a given problem [11]. The process of determining these parameters based on a collection of potential inputs and corresponding desired outputs is known as training the ANN, and optimizing training is of the most fundamental aspects of working with ANNs. Feed-forward networks can be trained using simple, well-understood methods such as stochastic gradient descent, which explains their popularity in the machine learning community [12]. Rapid advances have been made in the study of ANNs since 2006, when two algorithms that expedited the training of ANNs with large numbers of nodes and connections between nodes were discovered [13]. These techniques have led to the rise of "deep learning," which enables computers to use complex ANNs to process data and locate useful features in datasets without human input [9]. One design of feed-forward networks, known as convolutional neural networks, has found widespread popularity since deep learning became viable. Convolutional networks have seen great success when applied to disparate problems such as encoding data and processing images, as well as in integrating the results of different networks to produce optimal results [14]. Recurrent neural networks, which modify feed-forward neural networks by allowing data to be held in one layer instead of transitioning to the next, can be used to handle more specific problems, especially in natural language processing [12].

ANNs require a large amount of processing power to run, so researchers typically perform machine learning using specialized devices such as general-purpose graphics processing units (GPGPUs) [14]. This computational challenge means that running an ANN on an AR device for this project would be infeasible given the limited power of AR devices. A better option would be to run an ANN on a desktop computer with a graphics processing unit and to transmit data between an AR device and a computer via a wireless connection. This would enable the AR device to bypass some of its hardware limitations to make use of the benefits of ANNs.

2.3b Image Processing

Image processing refers to the processing of digital images into quantities of brightness and spatial coordinates [15]. There are many different uses and applications of image processing, but focussing on the specific areas of image processing that can be applied to AR technology, this includes 3D tracking, text recognition, and image connection using neural networks.

3D tracking is one of the most researched and cited topics in AR, as it is a fundamental technology for AR as it allows for the interpretation and therefore manipulation of the environment surrounding the user[16]. In addition there are many potential ways to implement 3D tracking in an AR system. Park et al. [17] researched one such way in which they described a method to track many objects in real-time; In order to track multiple objects, Park et al. created object models containing information about the target object captured, and then extracted “keypoints” and the 3D location from the object [17]. Then by obtaining points matched with points from previous frames, they estimated the pose of the object by fusing them with the previously extracted keypoints [17]. While this method accurately tracked objects with an adequate frame rate, it is limited by the database containing the object models used. This form of tracking is known as vision-based tracking, where information is gathered from a digital image [16].

Another method that uses image processing with 3D tracking is known as hybrid tracking, which combines both vision and other sensor based techniques. Klein & Drummond [18] proposed a hybrid tracking method that relied on a CAD model-based tracking system combined with gyroscopes to enable a system to track camera rotations, regardless of any motion blur that can occur. Head position was estimated and then aligned to computer-generated graphics on an AR display [18]. While this method was indeed capable of correcting distortion seen on AR displays, it was limited to a 30° field of view and to environments that can be easily represented using Computer Aided Drawing (CAD) software. [18].

Markman et al. [19] developed a method for better visualizing an object in 3D space on an AR device. They used axial distributed sensing, which is a technique that involves moving a camera at different depths in a scene, in order to better capture the 3D scene [19]. The images captured were then collected and divided into smaller parts called cells, and then reconstructed based on the gradient directions [19]. The recreation of the image could be displayed on an AR screen, without being obscured, and with information about the distance of the image [19]. While this technique is useful for recreating an obscured image, it is not able to accurately reconstruct a moving image. However, by combining this technique with the techniques described previously, recognition might become possible.

Another topic in the field of image processing that can be used in AR applications is text and handwriting recognition. Because there are so many different variations of text, in order for a system to accurately recognize and analyze the text, neural networks are often used. Hull [20] created an image database full of over seventy thousand different digital pictures of handwritten images. The database was more effective than other previously created database because others only took in singular characters, while Hull's database used full words that showed how characters change when written in conjunction with each other [20]. Even though this database allowed for others to experiment with grayscale recognition techniques and preprocessing, the images chosen for the database were limited to individual characters, city and street names, and zip codes [20].

Saidane & Garcia [21] used a similar database to train a convolutional neural network to recognize text from scene images, despite distortion and low resolution [21]. By using thirty thousand images in the training set, and with optimization through the training phase forty times, they were able to achieve an average recognition rate over ninety percent [21]. Wang et al. [22] researched how to extract information from natural images, instead of pre-chosen words from text documents. Instead of using "sophisticated models" such as pictorial structures or conditional random fields, they focused on using an unsupervised feature learning algorithm [22]. The learned features were then integrated into a convolutional neural network to build an end-to-end system with minimal post-processing techniques [22]. All of the algorithms described can be combined with an AR device to be able to accurately detect text in real life situations.

2.4 Devices and Platforms

Many different platforms can utilize AR technologies. These platforms fall broadly into two categories: head-mounted devices and mobile devices. Head-mounted devices such as the Microsoft HoloLens and the Meta 2 are less available, as they are still undergoing software development. Mobile devices are more widespread, as they are more accessible to the general public, with over 2 billion users worldwide [23]. However compared to head mounted devices, mobile devices have varying AR capabilities.

2.4a Augmented Reality Headsets

There are only a few head-mounted devices specifically tailored towards AR because of the relative novelty of the technology. The two devices currently released for general development are the Microsoft HoloLens and the Meta 2 [23], [24]. These devices, while still in early phases of development, offer an indication of the future accessibility of AR.

The HoloLens and the Meta 2 are holographic projection devices, which enable the user to place virtual objects onto the user's field of view and interact with the objects. The headsets are equipped with sensors and multiple cameras to map and create virtual representations of the users' surroundings. The head-mounted units use this simulation of the user's environment to attach holograms to physical surfaces convincingly. Through these technologies, these headsets promise a possible replacement of the current computer monitor paradigm [25].

Although AR technology is still in its infancy, it is already being used in some places with promising results. For example, the developers of the Meta 2 claim that the AR headset has already superseded monitors and that they use the Meta 2 to develop their products [25]. The HoloLens has also been marketed as a device that can have great utility in the workplace. Although AR headset technology is not yet advanced enough to overtake the current conventional paradigm, there are strong indications AR technology will be a large part of the future in productive settings. Many different sectors serve to benefit from the direct line-of-sight continuous information streams that these AR headsets can offer. One such sector is the military, which sees potential in the ability to use AR to visualize many different types of data, such as sonar trails in submarines [26]. AR also allows for greater communication in health [27] and other utilitarian and recreational uses [28]. Because these headsets are hands-free, they can be used to help people in everyday tasks, such as reading or writing, without becoming too cumbersome.

There currently exist several options for AR development, the number of which is steadily growing as AR technology continues to develop. Most of the Software Development Kits (SDKs) for AR use the Unity engine for 3D models, generally in the form of plugins. Some of the more widespread SDKs include the ARCore [29] from Google, ARKit [30] from Apple for use in iPhones, Microsoft's Visual Studio for the HoloLens [24] and PTC's Vuforia [31]. Because ARCore [29] and the ARKit [30] are mobile development SDKs, they also require the Android and Apple SDK, respectively. Vuforia [31] is packaged alongside Unity, whereas Visual Studio uses a Unity plugin to develop for the Microsoft HoloLens [24]. The Meta 2 utilizes the OpenVR and the Open Source Virtual (and Augmented) VR SDKs [32] to develop alongside Unity. Team ART hopes to utilize these headset and the SDKs available to create a program to help provide real-time handwriting correction for dyslexics.

2.4b Mobile Devices

The mobile platform is the most widespread platform for the development of AR applications. Of the estimated 2 billion smartphone users in the world [23], roughly 82% use Android base devices and roughly 18% use iOS based devices. Both iOS and Android have AR capabilities as mentioned previously, iOS with the ARKit, and Android with ARCore.

Both the types of devices and also the versions of the operating systems must be considered when working with mobile platforms. Not only do different versions tend to have their own idiosyncrasies, older versions tend to have fewer features than the more modern ones, limiting the scope of what software can be run on them. However, most smartphones do have a set of standard features, regardless of platform or operating system. In regards to providing real time hand writing correction for dyslexia, this project will most likely require camera and internet capabilities which are now standard for all devices [33]. However, because mobile devices are the most common platform, they have the greatest variety in quality of these features which needs to be considered when using them.

In addition to understanding the physical features of the mobile platform, it is also important to understand what software tools exist for creating an AR application. Many software development tools for the development of AR applications on smartphones already exist with built in functions for basic features. These features include support of Unity development platform, which is a common tool for powering the graphics of video games. Another feature important to AR apps is cloud recognition, which allows apps to access memory within the device itself to store "markers." The utilization of the cloud allows the app to store and recognize more markers than if the storage and recognition all occurred on the device. However, utilizing the cloud requires an internet connection. An application, like the one Team ART aims to develop, would require extensive storage for text and speech recognition and would benefit from cloud recognition despite depending on internet connection. Another feature necessary for AR app development kits is simultaneous localization and mapping, which allows the device to map an environment and keep track of its own position within it. The table in Fig. 1 summarizes the available software development kits for an AR application and which of these features each has, as well as the platform compatibility each kit offers.

	Vuforia	Wikitude	EasyAR	Kudan	ARTool Kit	Maxst	Apple ARKit
License	Free, Commercial	Commercial	Free, Commercial	Free, Commercial	Free Open Source	Free, Commercial	Free
Supported Platforms	Android, iOS, UWP	Android, iOS	Android, iOS, UWP, macOS	Android, iOS	Android, iOS, Linux, Windows, macOS	Android, iOS, Linux, Windows, macOS	iOS
Smart Glasses Support	YES	YES	NO	NO	YES	YES	YES
Unity Support	YES	YES	YES	YES	YES	YES	YES
Cloud Recognition	YES	YES	YES	NO	NO	NO	YES
3D Recognition	YES	YES	YES	YES	NO	YES	YES
Geolocation	YES	YES	NO	NO	YES	NO	YES

Fig. 1: AR software development kits and their features [34]

2.4c Review

The purpose of an AR device is to give the user an experience they would not be able to achieve on their own due to the limits of reality. AR has huge potential as an assistive device, especially for groups with disabilities that affect their perception of the environment. Dyslexia is a widespread example of such a disability, and AR technology provides the platform necessary to create a device that would make learning and communicating easier for such a demographic. After understanding the challenges faced by people with dyslexia, the platforms for AR devices, and the underlying algorithms for text and handwriting recognition, the next step for Team ART is to determine which combination of algorithms and platform can be most effectively leveraged to assist the largest group of people most effectively.

Chapter 3: Methodology

3.1 Methodology Overview

Team ART hopes to use AR to help the dyslexic community by answering the question: what features of an AR application are most effective for improving people with dyslexia's reading and writing abilities? In order to best accomplish this, Team ART needs to gather information on what the dyslexic community desires in an assistive device. Once this information is gathered, Team ART will need to determine how to process and manipulate written documents, check handwriting in real time, and finally evaluate the effectiveness of the system developed. The team will then create an AR application incorporating features proposed during the interviews and test the application on subjects with dyslexia in an effort to evaluate the effectiveness of the team's AR approach. To accomplish all of this, the proceeding research design will be followed.

3.2 Research Design

The first phase of this project will center around interviewing people with dyslexia or their parents, if the individuals are children. The goal of this phase is to determine what features the dyslexic community seeks in an assistive device and to determine whether or not AR applications would be appreciated by said community. Team ART will be focusing on getting information about what features for handwriting correction and document manipulation will be helpful. The second phase will involve an iterative development process, in which the programs and the prototype are designed and developed, and then controlled tests of the application are conducted. Tests will be conducted on the application to determine its accuracy and effectiveness in assisting users with dyslexia. Including a testing phase in each iteration will integrate user feedback into the design of the prototype as it is being developed

3.2.a Interviews

Interviewing people with dyslexia will provide valuable information on the needs and desires of the target population of Team ART's application, so that the application can be optimized for its users. To obtain relevant data, interviews should be conducted with people with dyslexia, with an emphasis on children with dyslexia because of the effect on learning in classrooms that dyslexia can cause. However, as children and people with dyslexia are considered vulnerable populations by the Institutional Review Board (IRB), it may be challenging to gain access for interviews [35]. If team ART is unable to gain access to children with dyslexia, interviews will be conducted on college students with dyslexia (who have less restrictions) or parents of children with dyslexia (who have no restrictions other than standard restrictions applied to all research subjects) [35]. Furthermore, due to older subjects' increased communication skills, interviewing them may yield more coherent and useful results.

Regardless of the subjects, the interviews will center around the needs and challenges of people with dyslexia. Potential questions include:

1. "What situations have you had trouble dealing with because of your (or your child's) dyslexia?"
2. "How do you (or your child) currently work with or compensate for your (or their) dyslexia?"

3. “What are some factors that affect your (or your child’s) ability to read printed and digital texts?”
4. “Would you (or your child) be willing to use an augmented reality device that could compensate for your (or their) difficulties in reading and writing?”
5. “What functionalities would you (or your child) be interested in having in an augmented reality application to counteract the effects of dyslexia?”

The answers to these questions will help guide the creation of an assistive device that meets the dyslexic community’s stated desires.

3.2.b Device Design

Team ART aims to implement Optical Character Recognition (OCR), and have it operate smoothly on a HoloLens or comparable AR device in order to help identify and correct handwriting. This involves first working on either refining a pre existing computer vision algorithm that already exists to identify and parse handwritten words, or working on a deep neural network machine learning algorithm that the team trains in OCR. Either method is viable, however, many open source OCR programs available online are not sufficiently specific enough for this proposal’s use case.

Writing code for the Hololens requires the use of Visual Studio and the programming language C# [36]. However, most machine learning Team ART uncovered through review of literature is done using the library TensorFlow, which works primarily in C++ or Python [37]. Additionally, the team’s computer vision library of choice, OpenCV, is written in C++ [38]. Therefore, the team will need to implement porting over to C# in order to run an effective application on the Hololens [36]. In addition, TensorFlow requires the computing platform Nvidia CUDA in order to run, so using TensorFlow would require the team to use an Nvidia equipped computer as a server in communication with the HoloLens in order to effectively leverage these platforms[37]. Introducing the need for an external server requires another step in creating OCR that works to the team's specifications on the HoloLens. The team also has to develop a user interface on the HoloLens itself that leverages the other work that the team has done so that individuals with dyslexia can effectively use the device.

3.2c Testing

After creating the application, Team ART will test the application's capabilities and determine how effective it is at helping people with dyslexia read and write. The team will begin by testing the subcomponents of the modular application to ensure that each subcomponent works as designed using a mixture of manual and automatic testing. After that, the team will enlist research participants with dyslexia from the student body at the University of Maryland and/or nearby K-12 schools which cater to students with dyslexia in order to evaluate the device's usefulness at improving reading and writing. Team ART hypothesizes that the ability of AR software to apply visual filters to documents and to notice and highlight written errors can lead to substantial improvements in people with dyslexia's ability to learn reading and writing.

Each discrete functionality of the application can be evaluated separately, independent of testing the prototype as a whole. These functionalities include algorithms for overlaying text and other aspects such as page color on paper with a nonstationary AR device and also algorithms for live handwriting recognition that can account for incorrect characters. These functionalities must be tested under different conditions before being integrated into the prototype as a whole. For example, using the AR device to overlay some aspects of a text over a page must be initially tested under different lighting conditions with different sizes, fonts, types of text, and different levels of head movement. This functionality would be best analyzed beside user experience and feedback. The application's ability to recognize handwriting can be tested on handwriting samples containing different mistakes, such as common mistakes mentioned in the initial interviews. The handwriting samples will be obtained via online submission from our social media and will be turned into a database. This data can be numerically analyzed by calculating the percentage of words identified correctly and incorrect words and characters identified correctly. If the application fails to perform any of these tasks, Team ART will continue to modify and refine the software until it is able to succeed to an acceptable level.

Once each functionality has been tested, the whole application will be integrated together to be tested on people with dyslexia. These tests will provide data on the benefits that people with dyslexia's experience when using the AR application. Two types of tests will be used: one to examine the application's effects on reading accuracy, and the other to examine its effects on handwriting accuracy.

To test the device's benefits for reading, Team ART will give participants a passage of typed text to read and time how long it takes participants to read while using the device. First, all research participants will be timed reading a passage without any assistance to give a baseline measure of their reading speed. After a break, participants will be given an AR device and another text passage. They will be given time to customize the application settings to their specific preference, because different types of dyslexia require different corrections and so every subject will need the device to perform different tasks. After participants have chosen the settings that work best for them, they will be given another passage to read while wearing the device. Their reading of this passage will be timed and compared to their baseline time to measure the effects of the AR device on reading. Participants will also be given a brief comprehension quiz after reading each passage to ensure that they are not skipping portions of the text. A control group with no access to the AR application will also be studied to control for various effects such as fatigue. Team ART expects that these tests will demonstrate that using the application provides a benefit to the dyslexic community's reading speed.

Tests of the real-time handwriting correction capability can be accomplished by reading a standardized set of texts to subjects with dyslexia and having them write out what is dictated at a consistent volume and pace. Dependent variables, such as the amount of time it takes subjects to transcribe the set and the amount of errors subjects make during the process, can provide insight into whether or not the device is working as desired. The results of and feedback from these tests can then be used in further iterations of designing and improving the application. For this, it will be best to collect two datasets per subject: one before trying on the device, one with the device on. The first set of data would serve as a baseline so that each subject's writing while using AR assistance (the second set of data) can be compared with prior data for that subject. To prevent the effects of fatigue from affecting the performance of the individual, the team will give participants short, five-minute breaks between each dictation session. Furthermore, some subjects will be placed in a control group which transcribes the two spoken texts without using any AR assistance. The results from this control group can be compared to the corresponding results for the experimental group to account for exhaustion or any other confounding variables.

This test is expected to show that the real-time handwriting correction techniques included in the application can increase the writing speed and legibility of people with dyslexia.

The team will also briefly survey the test participants after these tests as to their user experience with the device, in order to measure the aspects of the application that people with dyslexia liked, disliked, and felt could be modified or improved.

This phase of the research requires access to a sizable group of participants with dyslexia, and unlike the interview stage, there is no way to obtain results of the same caliber from a non-vulnerable population. Because these tests take place at a later date than the interviews, the team will have more time to review IRB feedback on the research design and optimize experimental procedures for working with people with dyslexia. The required population size should not be a problem, as the University of Maryland has a large student body, and subjects with dyslexia from said body can be recruited potentially with monetary compensation as an incentive. Additionally, Team ART hopes to recruit participants from nearby K-12 schools with a focus on students with dyslexia, however, also understands that these participants may be difficult to access due to being a vulnerable and protected population. If it proves impossible to work with people with dyslexia, it would be necessary to test the AR application on anonymous handwriting samples without letting potential users try the device. While this process would provide results on the accuracy and precision of AR handwriting correction, it would not give any information on whether or not the device gave any tangible benefit to people with dyslexia. Testing the device with real users with dyslexia would provide the most informative results for this study.

3.3 Subteams

Since there are many parts to this project, it is important to partition the work evenly throughout the team. In order to optimize the team's productivity, it will be divided into two subteams that will be responsible for different aspects of the project. These teams are the outreach/surveys team and the software/hardware team.

The the outreach team will be the smaller of the two. This team's objective is to meet with members of the dyslexic community, and collect data. Charged with the task of conducting surveys and interviews, this team will be the most vital in the early stages of the project. The outreach team will be in direct contact with primary sources of information which will ultimately shape the team's direction. The information gathered will include specifics on test subjects' specific types of dyslexia and what they commonly struggle with. Data collected will include common spelling mistakes, common characters that present problems, what changes to paper and font make reading easier, and what current tools are being used to assist with reading and writing. This subteam will also be responsible for upholding a relationship with the dyslexic community throughout the three years. Throughout the development and testing phases of the project, this subteam will process feedback from the community to be incorporated as the project moves forward. This subteam will also be in charge of maintaining a relationship with test subjects and informing interested individuals on the progress of research.

The outreach team's second objectives will include locating and contacting potential partners to assist the team with the project. Combining previous research and the expertise of medical professionals with the interviews of the dyslexic community will greatly advance the project. Examples of groups this team will be responsible for making connections with are medical institutions specifically focused on the treatment of dyslexia, individuals making advances in AR, and organizations to aid in funding. This subteam is kept small, because the bulk of their work will be done in the initial stages of the project. The members of this subteam will also aid the next subteam in various tasks.

The second subteam, the software and hardware team, will be responsible for the physical prototype and the programming of the application. This team will develop the code for the HoloLens that will be used in testing. After obtaining a HoloLens, they will experiment with said device and with AR software tools to become familiar with their functionalities, capabilities, and limitations. Due to the complexities of working with the HoloLens, coupled with the overall lack of previous knowledge about developing a program compatible with the headset, this team will be further broken down into four specialty teams, the goal of which is to cover different all intricacies of the development phase.

These four specialty teams will include the OpenCV, neural networks, porting, and HoloLens development teams. The OpenCV team will be responsible for the development of the code for the computer vision tasks of the project, which will include recognizing and altering the paper, and recognizing handwriting. The first step will be to examine and alter example code in C++ and the OpenCV library to develop original code for Team ART's specific application. The neural networks team will be simultaneously researching and developing a neural net for the program to learn how to recognize errors in handwriting. As mentioned before, developing on the HoloLens creates the complexity of transferring between specific languages. The porting team's task would be to take code that was either written, or obtained from a public library and make it compatible. The HoloLens team will then port that code into the machine. They will also be responsible for developing the user interface of the program. This will occur while interpreting all the information and suggestions from the other subteam.

Chapter 4: Conclusion

Team ART's goal is to utilize AR to aid those with developmental disabilities, specifically dyslexia, and help them succeed in reading and writing. The team plans to utilize the Hololens as an AR platform, as it is the most sophisticated and also has needed features for the team's needs. The team will train an open source neural network to identify incorrect handwriting; in addition, due to computing overhead, the algorithm will run on a machine connected remotely to the AR headset. Using this, the AR will analyse the writing and attempt to identify and help the writited correct the errors. Team ART plans to interview subjects with dyslexia at first in order to gain an understand what will be most effective in an application. The next step will be to build and test a prototype and test it against children with dyslexia if possible, in order to test the actual effectiveness. Our hope is that the results of this project can help those with dyslexia with reading and writing not only with the AR headset but also without; which can help those growing up with dyslexia be less disadvantaged, in school and everyday life.

Appendix A: Budget

TEAM ART BUDGET							
REVENUE	Fall '17	Spring '18	Fall '18	Spring '19	Fall '19	Spring '20	TOTAL
INCOME							
Gemstone	$300.00	$300.00	$300.00	$300.00	$300.00	$300.00	$1,800.00
Launch UMD	-	-	-	-	-	-	$0.00
Fundraising	-	-	-	-	-	-	$0.00
Grants	-	-	-	-	-	-	$0.00
Total	$300.00	$300.00	$300.00	$300.00	$300.00	$300.00	$1,800.00
EXPENSES	Fall '17	Spring '18	Fall '18	Spring '19	Fall '19	Spring '20	TOTAL
EQUIPMENT							
Hololens		$3,180.00					$3,180.00
Meta2		$1,623.70					$1,623.70
Computer							$0.00
Total	$0.00	$4,803.70	$0.00	$0.00	$0.00	$0.00	$4,803.70
PARTICIPANTS							
Preliminary Survey (1 x $25)		$25.00					$25.00
Headset Testing (30 x $15)				$300.00			$300.00
Total	$0.00	$25.00	$0.00	$300.00	$0.00	$0.00	$325.00
CONFERENCES							
Conference Cost							$0.00
Travel Fees							$0.00
Food Fees							$0.00
Housing Fees							$0.00
Total	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
MISC PAYMENTS							
Headset Cleaning Supplies							$0.00
Other							$0.00
Total	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
TOTALS	Fall '17	Spring '18	Fall '18	Spring '19	Fall '19	Spring '20	TOTAL
Total expenses	$0.00	$4,828.70	$0.00	$300.00	$0.00	$0.00	$5,128.70
Cash short/extra	$300.00	-$4,228.70	$300.00	$300.00	$600.00	$900.00	-$3,328.70

Appendix B: Timeline

In order to complete the project before Spring 2020, Team ART has laid out the following timeline for completing major milestones for testing, research, and device design.

Glossary

Algorithm - A process or set of rules to be followed, especially when performed by a computer.

Augmented Reality (AR) - Technology that superimposes computer generated images on a user's view of the real world.

Dyslexia - A disorder characterized by difficulty reading and writing words even with normal intelligence. Dyslexia can manifest in many different ways and can affect daily life to various degrees.

HoloLens® - An AR headset made by Microsoft which has the ability to add sounds and visual projections to the user's perception of reality [36].

Image Processing - A set of techniques used to analyze digital images with computer algorithms and break images up into quantities and special coordinates.

Machine Learning - A field of computer science focused on "teaching" computers how to accomplish tasks without explicitly programming them to do so.

Meta 2® - One of the two major AR devices on the market today, alongside the HoloLens.

Multimodal Interaction Mechanism - A system that allows multiple ways to interact with the input and output of the system.

Neural Network - A popular machine learning model with a structure inspired by the human brain. Neural networks are composed of "layers" of "neurons" in which each neuron takes input from neurons in a previous layer, processes its input, and sends data to neurons in the next layer.

Nvidia CUDA® - CUDA® is a parallel computing platform and programming model that enables dramatic increases in computing performance by harnessing the power of computers' graphics processing units (GPUs).

OpenCV - A software library that contains built in functions for computer vision algorithms including but not limited to object recognition, object tracking, the extraction of 3D models from images, and the establishment of markers to be overlaid with AR graphics [38].

Optical Character Recognition - The process of identifying letters, numbers, and other characters through their visual manifestations and storing this information on a machine.

Porting - The process of adapting software to be used on a platform other than that for which it was designed.

TensorFlow - A software library used for the building and training of neural network models, which allow computers to learn how to classify patterns and put inputs into proper groups without direct human instruction [37].

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