J.N. Andrews Honors Program
Andrews University

Proposal for Senior Honors Thesis

HONS 497 Senior Honors Thesis **Credits** ___2___ (2 minimum required)

Directions: Please submit a **digital version** of your signed proposal to the Honors Office, honors@andrews.edu **at least one week prior to your scheduled meeting with the Honors Council**. This proposal must be accepted by Honors Council the semester before presentation.

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Thesis Title: Developing a Computer Vision-based Mobile-Assisted Learning App for ASL Recognition
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Expected date of Graduation: May 2024

I. Provide goals and brief description of your project or research.

With over 466 million people worldwide experiencing hearing loss and a projection of that number rising to 700 million by 2050, the need for sign language learning is rapidly increasing [11]. To accommodate the increasing demographic of deaf and hearing loss individuals, several mobile-assisted language learning (MALL) applications aim to teach basic ASL. For example, ASL Bloom and Lingvano on the Apple App Store present videos of ASL signs for users to identify and recall. However, one key difference between ASL and other foreign language learning apps is that MALL apps for oral languages allow users to speak the target language themselves. Apps such as Duolingo and Rosetta Stone enable users to speak into their mobile device's microphone, and the app will provide instantaneous feedback on their pronunciation [10]. Such feedback is necessary for effective language learning [2, 3]. However, many of the ASL learning apps do not provide an opportunity for the user to sign a word themselves. As a result, current ASL MALL apps cannot provide the necessary feedback to prevent users from mis-signing words. The lack of feedback highlights another challenge for learning ASL: beginner signers cannot self-monitor ASL pronunciation as they can for an audible language, and they must overcome the discomfort of using hand motions [6]. Although current ASL learning apps can help learners identify signs, it does not allow them to become confident in signing words themselves.

To address the lack of ASL learning feedback, several researchers have devised several methods for sign language recognition (SLR) with machine learning (ML) [5]. Such methods use a device's camera or webcam to capture a user attempting a sign. The machine learning model will then use computer vision (CV), a subset of ML specifically for classifying image and video data, to determine what word the user is signing. While several methods have been proposed in academic literature, many of these CV algorithms were only applied to desktop computers rather than mobile devices, making them less accessible for portable language

learning. For models applied to mobile applications, datasets for such algorithms were relatively sparse, such as only being able to recognize 25 signs [9]. As a result, my project seeks to improve current SLR implementations for ASL learning apps.

The primary goal of my project is to create a mobile application that supplements ASL learning by utilizing computer vision to provide feedback on a wide range of ASL signs. I will build the app using a React Native framework, as it allows cross-platform compatibility (i.e., available on both iOS and Android). To accommodate a broader range of ASL signs, I will use the 2000-sign dataset, called the WLASL dataset, produced by Li et al., and I will implement their I3D machine learning model [1]. Since the I3D model was written in Python, I must determine how to implement Python code into a React Native application. In addition, building the app will require answering other questions, such as how to capture, access, and analyze video data from the mobile camera and how to display data in an interactive, visually appealing manner. The resulting app will display feedback when a user signs a word. When a user attempts to sign in front of their mobile device's camera, my app will use the I3D model to analyze the user's video data and determine the word they signed. If the word the model chooses matches the word the user intended to sign, then the user signed correctly. Otherwise, the app will provide feedback stating that the app was unable to recognize the sign. The app will also display a video with the correct signing of the intended word and make a side-by-side comparison with the user's video data.

II. Outline your methodology. **Please be specific**. How does this achieve your goals and how reliable is it?

The methodology of this project consists of the following stages: analysis, design, development, and testing. The analysis portion entails determining the requirements for an effective ASL application. It means answering the question, "What features does the first version of my app need to be successful?" Answering this question requires a literature search regarding the current issues with ASL learning apps (which I have already completed for this proposal). I have also connected with an ASL teacher to gather information about some common challenges beginner signers face. Furthermore, the literature search must analyze the strengths and weaknesses of current MALL apps and decide which features I must include. Since this is only the first version of my app, I will focus on only including elements that are strictly necessary for the app's functionality as outlined in my goals, which include (but are not limited to) app navigation buttons, video displays, and feedback about the user's signing correctness. I will make note of other features, such as including game elements or mentioning cultural behaviors in the Deaf community, which can be saved for future research. However, I will direct my attention to the strictly necessary features. Clearly defining a checklist of essential app features in the analysis stage will ensure I stay focused on the scope of my project. It will also guide me in designing my app's visual components and technological infrastructure in the next stage.

In the design stage, I will plan the app's front and back end. In doing so, I will conceptualize the features from the analysis stage by creating mock-ups for the front end and diagrams for the back end. Creating mock-ups and diagrams will enable me to determine what exactly needs to be coded for the next stage of the methodology. It will also help me identify how different aspects of the app must interact to achieve the goals of my project. For the front end, I must design not only how the app looks but I must also determine the content of each page, answering the questions, "What information does the user need to navigate the app effectively?

What does the user need to see to learn ASL?" The front end will provide that information with written content, video content (for ASL signs), and a graphical user interface. While the front end allows the user to interact with the program, the back end handles the processing of information. Designing the back end means outlining the technological infrastructure, as shown in the diagram below.

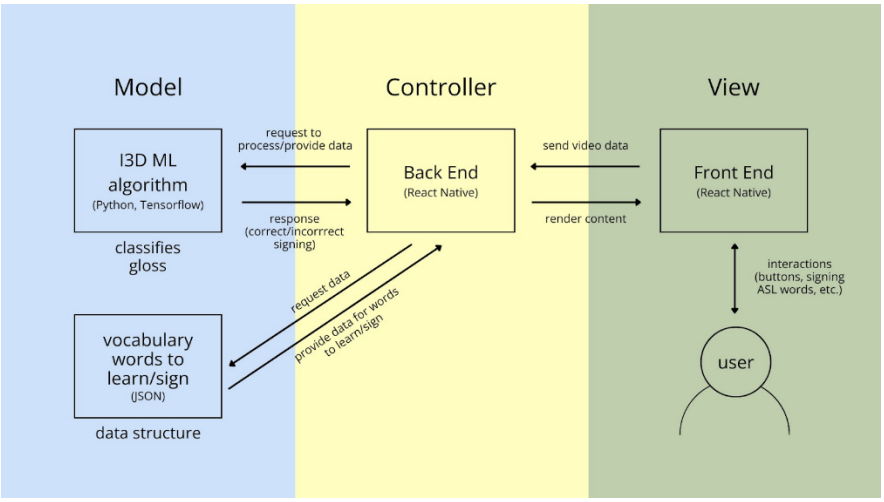

Figure 1. An MVC architecture for the proposed mobile application for ASL learning

As outlined in the diagram, my app will use the Model-View-Controller (MVC) architecture, often used for mobile applications, to handle different aspects of my app. Currently, I intend to perform all the ML processing locally, meaning that the classification of the user's attempted sign will be processed on their phone alone. Local processing protects the user's privacy as none of their video data is sent to an external server. However, I intend to use an external server only to store the data structure of possible vocabulary words a user can sign. Having an external server for such a large dataset will ensure that the app does not require extensive mobile device storage space. The specifics of the MVC architecture outlined in my diagram will be explained in greater detail in my final paper.

The most time-intensive portion of my project will be the last two stages of my methodology–the development and testing stages–which I will perform simultaneously. In this stage, I will code the app using the React Native framework and build the app with Expo. As for the back end, I will implement the computer vision model using the open-source ML platform TensorFlow. TensorFlow will enable the integration of the Python-coded I3D algorithm into React Native. I will simultaneously develop and test my app by incorporating the software engineering practice of continuous integration (CI) [7]. These practices are typically applied to large-scale companies with many developers, in which developers may accidentally "break" the source code with the new code they added. To solve this, programmers "push" their edited code to the main codebase daily (CI) to test if it still integrates seamlessly with the existing code. While these methods typically involve creating automated tests, to save time and stay focused on the scope of my project, I will run tests manually but regularly, such as at the end of each day of coding. With CI practices, I will be able to make sure my code runs throughout the development of the app; I do not need to wait for each component to be completed before I can test if it works. Doing so enables me to identify bugs as I am coding, preventing complex integration issues. As a result, using Expo to build my React Native app provides the benefit of making sure the app always runs successfully on a mobile device.

III. Explain in what sense your project is original, unique, or beyond normal senior expectations. How does it relate to current knowledge in the discipline?

This project is unique in that, to my knowledge, there is not yet a cross-platform MALL solution that uses an extensive dataset of ASL words for sign language recognition. As previously stated, academic literature proposes several different computer vision algorithms for SLR, but most still need to seek compatibility for mobile devices. The portability of a mobile app would make ASL learning more accessible to users. As for the few algorithms implemented on mobile devices, such as that of Paudyal et al., they could only recognize a relatively small number of signs [9]. To overcome this limitation, my project will incorporate a large dataset, Li et al.'s WLASL dataset, while still being storage-efficient for users. In building on the works of Li et al. and Paudyal et al., my research will benefit society by producing a cross-platform mobile ASL learning application that provides a more comprehensive vocabulary of possible signs to learn.

IV. Include a substantive annotated bibliography of similar or related work.

[1] Dongxu Li., Cristian R. Opazo, Xin Yu, and Hongdong Li. 2020. Word-Level Deep Sign Language Recognition from Video: A New Large-Scale Dataset and Methods Comparison. 2020 IEEE Winter Conference on Applications of Computer Vision (WACV), (21 Jan. 2020). https://arxiv.org/abs/1910.11006

In this paper, Li et al. produce a public ASL dataset, named the WLASL dataset, with over 2000 words performed by more than 100 signers. They also compare four different deep learning models for sign language recognition, one of which is the I3D method. The I3D model was shown to be the most accurate in their experiments, reaching up to 84.33% accuracy for a 1000-word dataset and 66.31% accuracy for a 2000-word dataset. I intend to utilize their dataset to produce an application that can recognize more signs than other mobile applications have been able to do. I will apply the I3D approach for sign language recognition.

[2] Fabienne M. Van der Kleij, and Remco C. W. Feskens, Theo J. H. M. Eggen. 2015. Effects of feedback in a computer-based learning environment on students' learning outcomes. Review of Educational Research, 85(4), (1 Dec. 2015), 475–511. https://doi.org/10.3102/0034654314564881

This study analyzes the effect of feedback on computer-based learning methods. The analysis shows that feedback that provided explanations had a more positive impact on students than feedback that simply provided the correct answer. I will reference this study in the introduction of my paper to demonstrate the effectiveness of offering feedback in learning environments, explaining the significance of AI sign language recognition in my project.

[3] Fu L. Wang, Ruofei Zhang, Di Zou, Oliver T. S. Au, Haoran Xie, Leung P. Wong. 2021. A review of vocabulary learning applications: From the aspects of cognitive approaches, multimedia input, learning materials, and game elements. Knowledge Management & E-Learning, 13(3), (2021) 250–272. https://doi.org/10.34105/j.kmel.2021.13.014

In this study, Wang et al. review 15 English as a Foreign Language learning apps in China, proposing a theoretical framework for analyzing the efficacy of learning apps. Their framework suggests that an effective language learning app incorporates a balanced amount of four elements: cognitive approaches (associating a word to a concept), multimedia input, learning strategies (such as exercises and examples), and game elements (such as time limits, interactivity, feedback, and levels). This framework will guide me in producing an app that effectively supplements ASL learning by applying these elements to my app.

[4] Geraldo M. Salomé, and Lydia M. Ferreira. 2018. Developing a Mobile App for Prevention and Treatment of Pressure Injuries. Advances in Skin & Wound Care, 31(2), (February 2018), 1-6. DOI: 10.1097/01.ASW.0000529693.60680.5e

This paper describes Salomé and Ferreira's process of creating an Android application for evaluating wounds and providing treatments. Their methods in planning and developing the application–namely, the criteria they used to make decisions about their app's features–and their presentation of their findings and results inspired my methodology. I will use this paper to guide my research methods and the structure of my final paper.

[5] Ilias Papastratis, Christos Chatzikonstantinou, Dimitrios Konstantinidis, Kosmas Dimitropoulos and Petros Daras. 2021. Artificial Intelligence Technologies for sign language. Sensors (Basel), 21(17), (30 Aug. 2021). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8434597/

This comprehensive survey analyzes the current sign language capturing, recognition, translation, and representation methods while evaluating their strengths and weaknesses. The section about sign language recognition is especially relevant to my project as it provides insight into the current areas of improvement. This paper will guide me in developing an app that improves the discipline's existing knowledge.

[6] Mike Kemp. 1998. Why is Learning American Sign Language a Challenge? American Annals of the Deaf, 143(3), (July 1998), 255–259. http://www.jstor.org/stable/44392557

This paper discusses five main factors contributing to the difficulty in learning American Sign Language. To do so, Kemp analyzes several studies on second language learning and applies them to the properties of ASL. The result is five proposed factors contributing to ASL learning challenges, one of which is language shock–specifically, the ability to self-monitor pronunciation with one's ears. I intend to address the language shock challenge by allowing users to see themselves on camera while learning a sign. In providing challenges of learning ASL, his paper will guide me in creating an effective language-learning mobile app by addressing the proposed challenges.

[7] Mojtaba Shahin, Muhammad A. Babar, and Liming Zhu. 2017. Continuous integration, delivery and deployment: A systematic review on approaches, tools, challenges and practices. IEEE Access, 5, (22 March 2017), 3909–3943. https://doi.org/10.1109/access.2017.2685629

This study analyzes the use of continuous integration (CI), delivery (CDE), and deployment (CD) in the software development industry using the Systematic Literature Review method. The study reveals that CI approaches to software development have been shown to reduce build and test time. Additionally, although there were several challenges regarding CI, CDE, and CD, it is increasingly becoming a mainstream approach in the software development industry, and several papers encourage its use. This paper guided me in choosing to incorporate CI/CDE/CD in the development stage of my methodology, resulting in a simultaneous development and testing stage.

[8] Nam Pham, and Thao Ho. 2020. Voice analysis with Python and React Native. Bachelor's thesis. Turku University of Applied Sciences, Turku, Finland. https://www.theseus.fi/handle/10024/342889

In this paper, Pham and Ho implement a machine learning algorithm to React Native for a cross-platform mobile application that conducts vocal analysis. The article outlines the advantages and disadvantages of frameworks that enabled the integration of Python as a back-end of a React Native application. As a result, this paper will guide me in implementing a Python algorithm into React Native. The research questions they posed also influenced the questions I wanted my project to answer.

[9] Prajwal Paudyal, Junghyo Lee, Azamat Kamzin, Mohamad Soudki, Ayan Banerjee, and Sandeep K.S. Gupta. (2019). Learn2Sign: Explainable AI for Sign Language Learning. IUI Workshops. https://ceur-ws.org/Vol-2327/IUI19WS-ExSS2019-13.pdf

In this paper, Paudyal et al. create an Android application for learning sign language, proposing a recognition model that uses the relatively simple methods of cosine similarity, dynamic time warping, and CNN feature extraction. They created a dataset of 25 ASL signs, each signed by 100 users three times. This paper provided insight into improvement areas, such as creating an app available across different mobile platforms (iOS and Android) and using a larger dataset.

[10] Rosetta Stone, Ltd. 2023. Rosetta Stone: Learn Languages. (Version 8.27.0) [Mobile app]. Apple App Store. https://apps.apple.com/us/app/rosetta-stone-learn-languages/id435588892

This mobile application provides learning modules for several oral languages, providing immediate feedback to users about their pronunciation of words. I will cite this in the introductory paragraph to demonstrate where ASL learning apps need improvement.

[11] World Health Organization. 2023. Deafness and hearing loss. World Health Organization. (27 Feb. 2023). Retrieved October 20, 2023 from https://www.who.int/news-room/fact-sheets/detail/deafness-and-hearing-loss.

This webpage provides an overview of the causes, impact, prevention, and management of deafness and hearing loss worldwide. I will cite this source and the statistics it gives in the introduction of my paper.

V. Provide a statement of progress to date and list the research methods coursework completed.

I have completed the Machine Learning, Mobile Application Development, and Software Engineering courses at Andrews University. As a result, I am competent in my understanding of neural networks, the MVC architecture, and the software development lifecycle as needed by my project, and I am equipped to build on my current knowledge. I have already begun the literature search regarding the limitations of existing ASL MALL apps and the needs an ASL MALL app should address. To date, my search has yielded the following helpful academic articles: four articles directly related to learning sign language or learning about the Deaf community, three articles regarding the efficacy of MALL apps, three articles about the mobile application development process, and three articles discussing ML algorithms for SLR, for a total of 13 sources shaping the goals and influencing the methodology of my project. In addition, I am in contact with Starla Roberts, a Master's student at Andrews University with a Bachelor's degree in ASL. She is currently teaching ASL classes on campus, and I have discussed with her the features my app should include to supplement ASL learning. Furthermore, I have also downloaded the WLASL dataset provided by Li et al., and I am currently reproducing their results before implementing it into a mobile app. Once I have trained and tested the WLASL dataset and I3D algorithm, they will be ready for mobile app implementation.

Department Chair Approval

- **This student's performance in his/her major field is acceptable.**
- **He/she has completed the requisite research methods coursework for the research to be pursued.**
- **I understand that he/she plans to graduate with Honors.**

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Department Chair (signature)

Research Advisor Approval

I have read and support this proposal: Ackley Will
Primary Advisor (signature)

I have read and support this proposal: William D Wolfer
Secondary Advisor (signature)

If human subjects or if live vertebrate animals are involved, evidence of approval from the Institutional Review Board or an Animal Use Committee is needed through the campus scholarly research offices (Ext. 6361).