Improving Professional Training and Education Engagement with Accessible Augmented Reality

Project F16 by Aidan Liu and Jeremy Flint
Non-RRI Project
10th Grade

INTRODUCTION

Following the start of the COVID-19 pandemic in 2020, 10.8 million people in the US were unemployed, which was an increase of 4.9 million since 2019. In many professions, such as industrial labor and automobile mechanics, training in the precise use of tools and hand movements is crucial to qualifying for the profession. However, these training programs can often be expensive and inaccessible due to material cost. Training for factory workers is around $1,000, and can reach upwards of $20,000 for automotive mechanics. Furthermore, the distance learning model that was adopted during the pandemic led to a decrease in classroom engagement, which was especially detrimental to younger students.

Existing solutions such as online courses are not interactive enough to provide the necessary training. Additionally, both current virtual and augmented reality technology require specific hardware to function. Moreover, augmented reality tools only provide guidance and still require the physical presence of equipment and materials. This lack of availability of professional training can lead to a smaller workforce as well as a larger population of untrained and unemployed Americans.

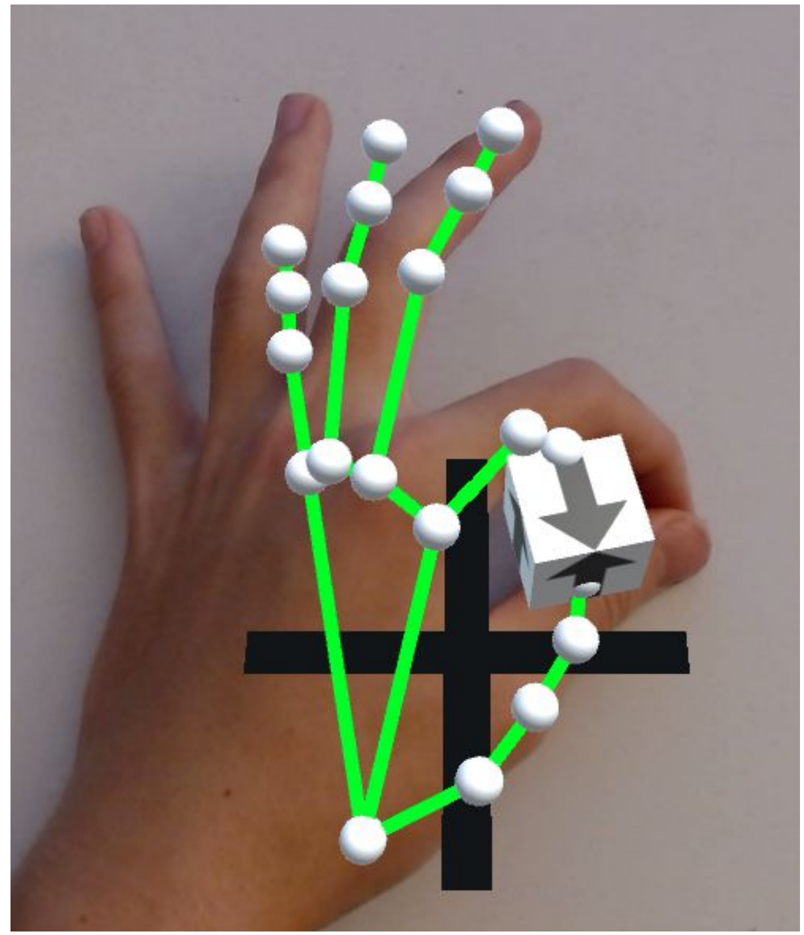
The goal of this project is to bridge these gaps through a unique, Unity-based mobile app with realistic and interactive augmented reality to increase educational engagement as well as improve access to professional training.

METHODS - Final Design and Implementation

The final design is a mobile app that takes live camera input and searches the image for the user's hands using NatML and Mediapipe. If a hand is detected, the app creates a virtual object in the position and orientation of the user's hand that matches the user's hand position and gesture. This virtual object is updated every frame to create a continuous imitation of the real hand. If the user attempts pinch their index finger and thumb or close their fingers over their palm, the app will detect the gesture and grab any virtual objects within a certain distance of these gestures.

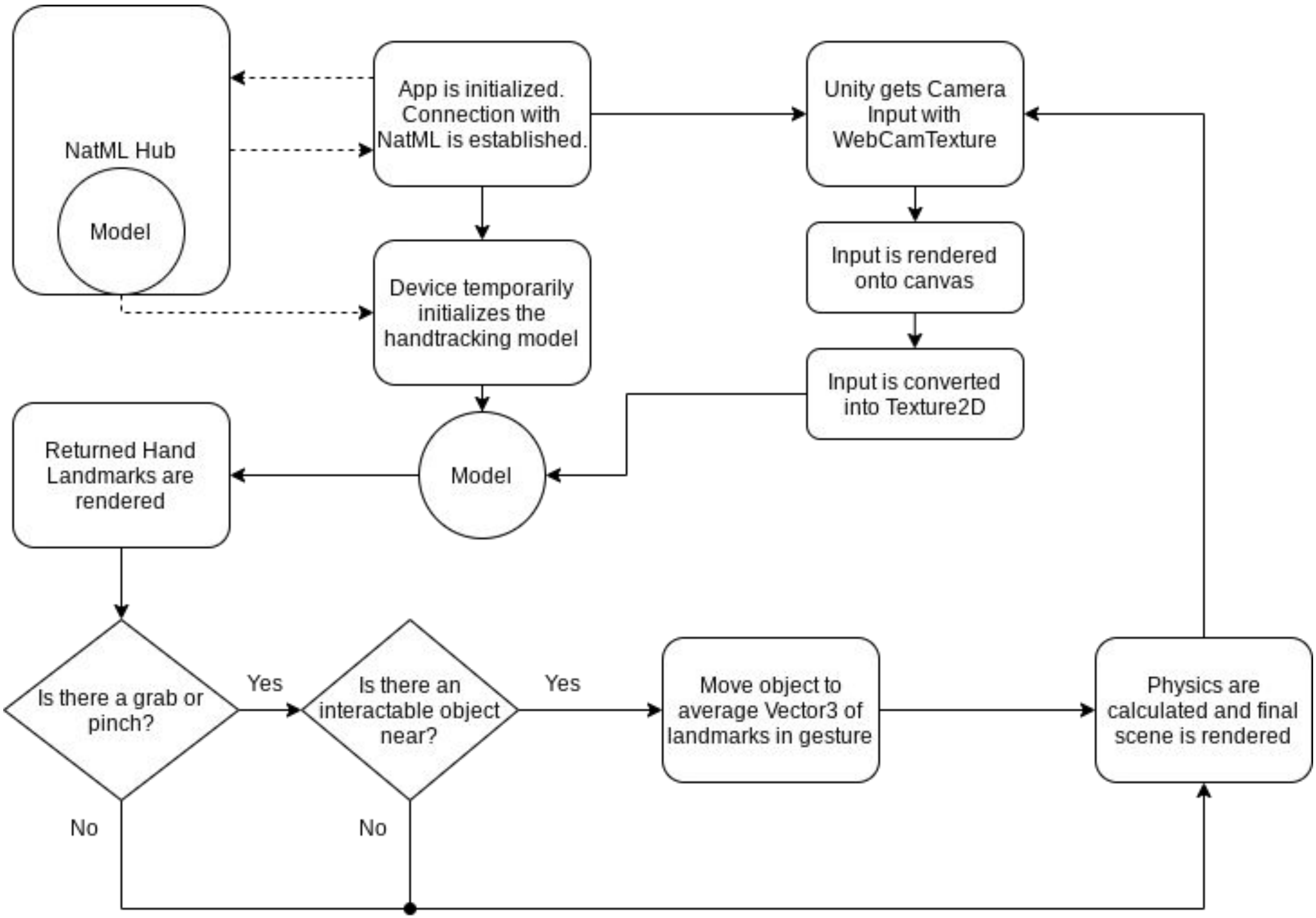
Grabbed objects will remain in the user's hand until the pinching/holding gesture is stopped, and will move around with the hand until dropped. By this method of interaction, users can learn to use tools that they would otherwise not have access to.

Demo video: https://youtu.be/UZq2preLNIY



An example of our hand interaction, the pinching gesture is grabbing the interactable box

METHODS - Final Design (Continued)

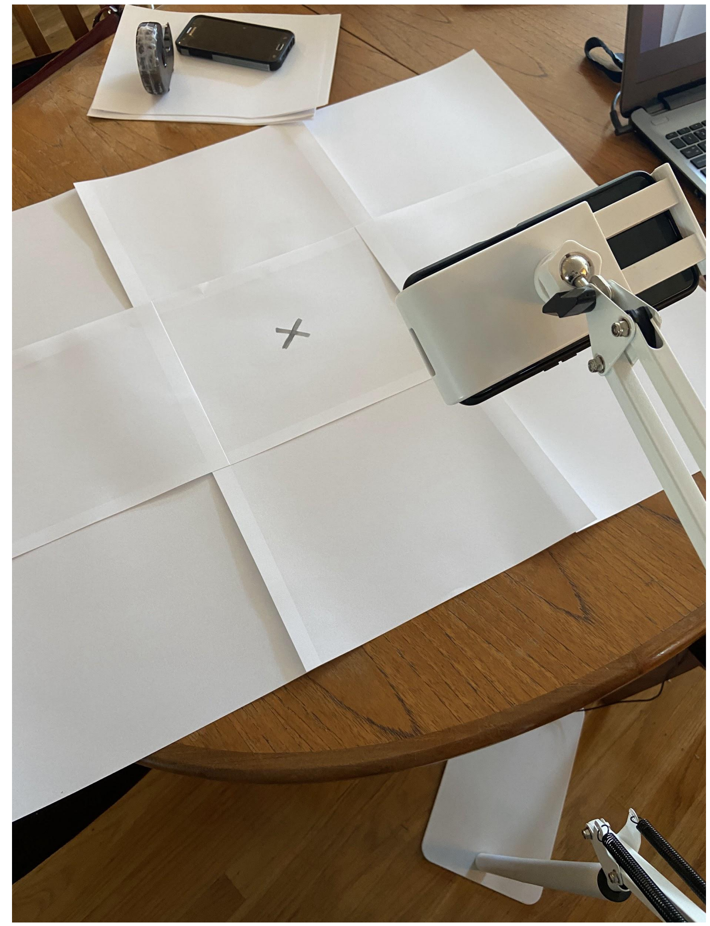


METHODS

The app was created using Unity 3D. Using Unity simplified physics calculations and importing packages into the project, and also allowed for easily building the app to different types of devices, such as the Windows computer it was coded on and the Android phone it was tested on.

We tested the app in three different aspects: how accurately the app could track the user's hand, how far the user could move their hand before the app no longer detects it, and how quickly and how long the user could pick up and hold a virtual object for. The testing setup for all three tests is as follows:

1. Open and begin streaming the app from the phone to Discord, and view the app from a computer
2. Place the phone in the stand, and adjust it to a 60 degree angle of depression
3. Align the X on the app to the X on the white sheet, which is placed in front of the camera on a horizontal plane



The testing setup; paper is used to maintain a solid background

METHODS - Testing Procedures

Accuracy Test:

1. Place the finger you are currently testing on the real life X
2. Adjust the finger's position until the virtual hand is on the virtual X
3. Measure and record the distance between the real life finger and X
4. Repeat steps 4-6 for each hand and finger

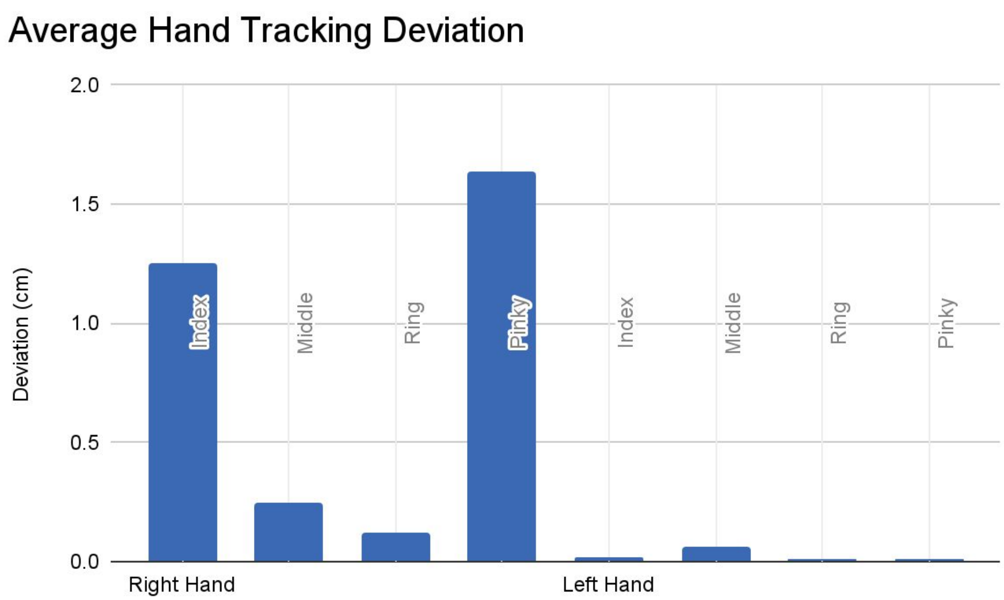
Range Test:

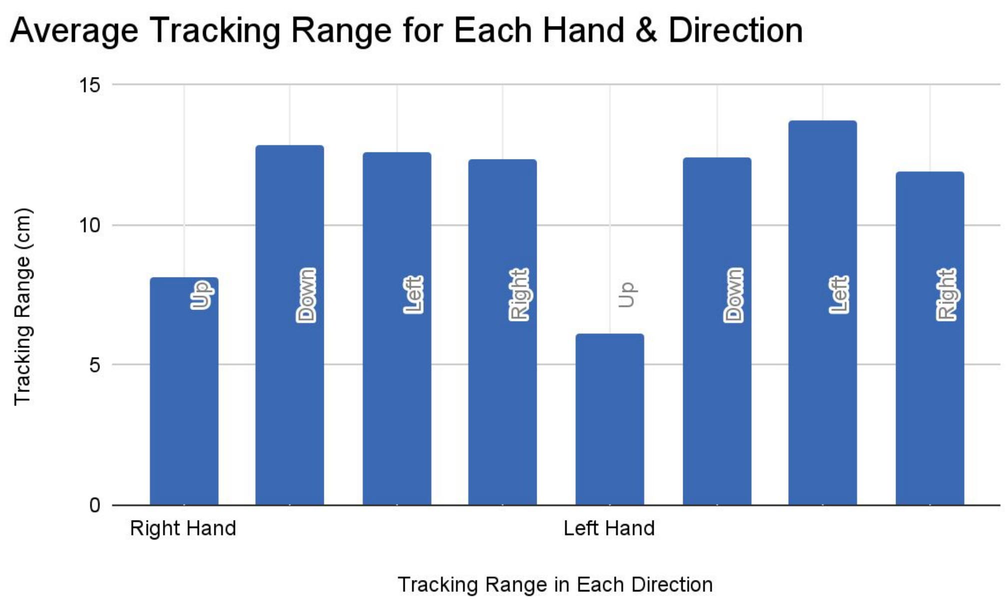
1. Mark the center of the palm of the hand and center it on the real life X
2. Move the hand in a direction until hand tracking stops, measure and record the distance
3. Repeat for both hands and all directions

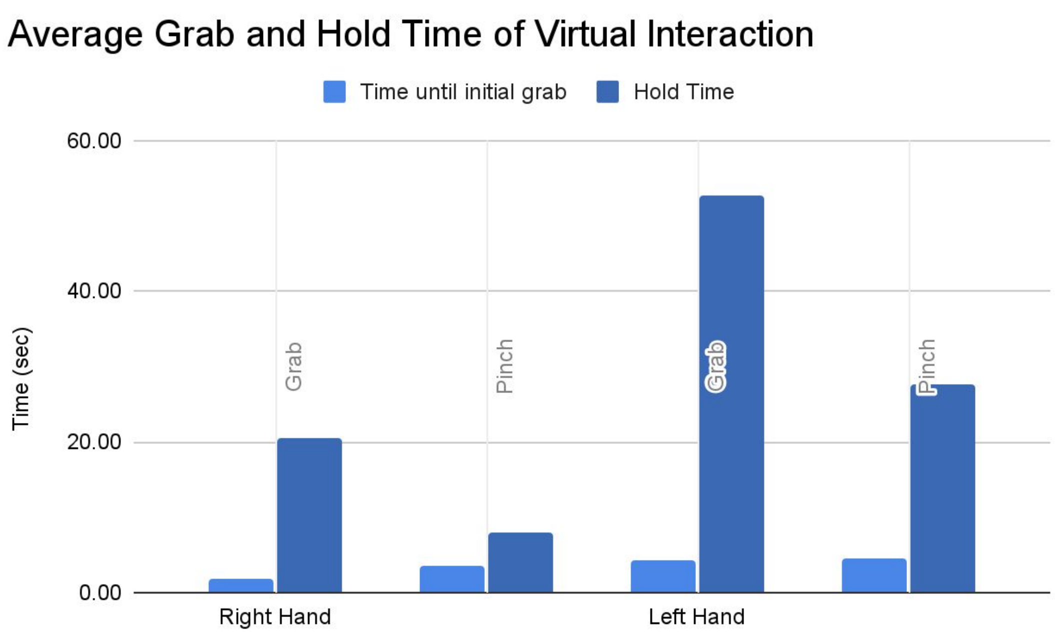
Interaction Test:

1. Wait for the screwdriver object to drop into the scene from above.
2. Attempt to pick up the screwdriver with the selected interaction motion, record how long it takes to pick it up
3. Move the hand in a deviation of 3 cm from the center of the screen in every direction
4. Record how long the screwdriver remains grabbed
5. Repeat steps 4 and 5 for different hands and grabbing motions

RESULTS


Average Hand Tracking Deviation
2.0
1.5
1.0
0.5
0.0
Deviation (cm)
Index
Middle
Ring
Pinky
Index
Middle
Ring
Pinky
Right Hand
Left Hand


Average Tracking Range for Each Hand & Direction
15
10
5
0
Tracking Range (cm)
Up
Down
Left
Right
Up
Down
Left
Right
Right Hand
Left Hand
Tracking Range in Each Direction


Average Grab and Hold Time of Virtual Interaction
Time until initial grab
Hold Time
60.00
40.00
20.00
0.00
Time (sec)
Grab
Pinch
Grab
Pinch
Right Hand
Left Hand

RESULTS (Continued)

In the accuracy aspect of hand tracking, our device averaged a deviation of around 0.42 centimeters, which successfully fulfilled our criteria. However, there were also two outliers that made this average much higher than it otherwise would have been, being the index finger and pinky of the right hand. Without these outliers, the average is only around 0.01 centimeters of deviation.

The maximum tracking distance averaged around 11.28 cm of range. Though changing the camera's distance from the plane can change its field of view, this range test was conducted with the camera 38 cm away from the plane, as far as possible from the plane while still allowing the hand to be detected at all While we did not originally have a tracking range criterion, during this test we found that the maximum distance from the camera to the plane did not meet our distance criterion.

The final aspect of our design was the virtual interaction. In this, we tested both how long it took to grab the object, as well as how long the object was held while moving the hand around. The average initial grab time was around 3 seconds and the average hold time was about 27.20 seconds. However, the hold time was more of a reflection of the range of our detection, rather than the interaction itself because once the hand leaves the maximum tracking range, any held objects are dropped because the hand is no longer detected to be making a holding gesture.

DISCUSSION

The most unexpected and largest issue in our design was its range. We had not originally accounted for this in our criteria, but noticed it during our preliminary testing. Because of this, we decided to further test it, only to find that its average range was only around 11.28 cm, which doesn't leave much room for user interaction.

Additionally, our current design requires some sort of stand and manual plane calibration, both of which restrict its usability and accessibility. In the future, this can be solved with the usage of tools like Vuforia and ARkit, both of which integrate easily with Unity.

Nonetheless, the integration between MediaPipe and Unity as well as the real time gesture recognition are big steps towards this design finding real application in education and professional training.

CONCLUSIONS

This app allows for interaction with objects and scenes that would otherwise be impossible or very difficult for some people to access. While the app's functionality is limited by its maximum hand detection range, its accuracy and reliability within that maximum range allows for a heightened level of interaction to all users across any location. The success of our testing proves the app's utility and potential to shape the future of professional training and educational engagement. Furthermore, the technology can be expanded and adapted to find application in a variety of fields and issues.

The main points that we would focus on improving if we continued to iterate on this design would be the range of detection and general performance of the app. As described above, the maximum range of the app limits it to a significant degree, which we could improve with a more streamlined implementation of Mediapipe hand tracking and detection. This would also likely improve performance, which does meet the criteria, but could still be greatly improved. Additional improvements include implementation of the Vuforia Unity package, which would allow a smoother experience by allowing camera movement without disrupting the hand detection and object placements, giving an option for using and tracking two hands, and more interaction options for users of the app (i.e. more objects, gestures, and scenes among others).

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