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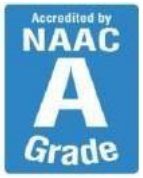

Hand Motion Detection and 3-D Interaction in Augmented Reality Using OpenCV and Unity

CAPSTONE PROJECT REPORT

Submitted by

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ABSTRACT

Accurate real-time hand motion detection and 3-D interaction are essential for seamless integration of augmented reality (AR) applications. This paper presents a comprehensive methodology to enhance hand motion detection and 3-D interaction in AR environments by leveraging advanced techniques in computer vision and interactive technologies. By integrating OpenCV and Unity, the proposed approach addresses challenges related to precise hand tracking and intuitive 3-D interaction. State-of-the-art algorithms are employed to detect and track hand movements accurately, enabling users to interact naturally with virtual objects in real-time. Through a series of experiments and evaluations, we demonstrate the effectiveness of our method in improving detection accuracy and robustness under various conditions. Furthermore, we provide insights into the computational efficiency and practical feasibility of the proposed solution, paving the way for its potential deployment in AR applications. This research contributes to advancing the state-of-the-art in hand motion detection and 3-D interaction, offering promising avenues for future developments in AR technology.

Keywords: hand motion detection, 3-D interaction, augmented reality, OpenCV, Unity, computer vision, real-time tracking, detection accuracy, robustness, experimental validation, computational efficiency, practical deployment.

CHAPTER I

INTRODUCTION

1.1 Introduction

In recent years, the fusion of hand motion detection and 3-D interaction has become integral to numerous applications within the realm of augmented reality (AR) and interactive systems. The accurate tracking of hand movements and their integration into virtual environments is fundamental for facilitating natural and immersive user experiences. However, achieving precise calibration and interaction in real-time poses significant challenges, particularly in dynamic environments characterized by complex backgrounds and varying hand poses.

Traditional methods of hand motion detection and interaction often struggle to cope with these challenges, resulting in decreased accuracy and robustness in practical scenarios. Background clutter can introduce noise and distractions, hindering the accurate tracking of hand movements, while variations in hand poses further complicate the interaction process.

To address these issues, this paper proposes an innovative approach to enhance hand motion detection and 3-D interaction in augmented reality environments by leveraging advanced techniques in computer vision and interactive technologies. By integrating OpenCV and Unity, we aim to mitigate the impact of background clutter and hand pose variations, thereby improving the accuracy and robustness of hand motion detection and interaction.

The integration of background removal techniques enables the isolation of relevant foreground objects or hands, reducing distractions during the interaction process. Additionally, leveraging Unity's capabilities, we aim to provide a seamless and intuitive user experience by incorporating realistic 3-D interaction with virtual objects.

Through a series of experiments and evaluations, we demonstrate the effectiveness of our proposed approach in enhancing hand motion detection and 3-D interaction performance across various scenarios. We evaluate factors such as accuracy, robustness, and computational efficiency, providing insights into the practical feasibility and potential applications of our method in augmented reality environments.

1.2 Statement of the Problem

Hand motion detection and 3-D interaction in augmented reality environments are crucial for providing immersive and intuitive user experiences. However, achieving precise calibration and interaction in real-time poses significant challenges due to background clutter and variations in hand poses. Traditional methods often struggle to address these challenges effectively, resulting in decreased accuracy and robustness in practical scenarios.

Therefore, the problem this research aims to address is: How can hand motion detection and 3-D interaction be enhanced to improve accuracy and robustness in dynamic augmented reality environments characterized by background clutter and variations in hand poses?

This problem encompasses the need to develop innovative techniques that can mitigate the impact of background clutter, accurately track hand movements despite variations in hand poses, and ultimately enhance the accuracy and robustness of hand motion detection and 3-D interaction in augmented reality environments.

1.3 Need for the Study

The need for enhancing hand motion detection and 3-D interaction in augmented reality environments is paramount due to its implications for various applications. Accurate hand motion detection and interaction are essential for providing immersive and intuitive user experiences in augmented reality applications, such as gaming, virtual training simulations, and interactive storytelling.

Additionally, advancements in hand motion detection and 3-D interaction can benefit fields such as human-computer interaction, robotics, and rehabilitation technology. By improving the accuracy and robustness of hand motion detection and interaction, this research can contribute to the development of more effective and inclusive augmented reality experiences.

1.4 Scope of the Study

The scope of this study encompasses the development and evaluation of techniques to enhance hand motion detection and 3-D interaction specifically tailored to dynamic augmented reality environments characterized by background clutter and variations in hand poses. Key aspects of the study include:

- Investigating state-of-the-art methods for hand motion detection and tracking using OpenCV.
- Exploring approaches for integrating hand motion detection and 3-D interaction into Unity for augmented reality applications.
- Developing algorithms and workflows to mitigate the impact of background clutter and variations in hand poses on hand motion detection and 3-D interaction.
- Conducting experiments to evaluate the accuracy, robustness, and computational efficiency of the proposed techniques in dynamic augmented reality environments.
- Assessing the practical feasibility and potential applications of the proposed techniques in various domains, including gaming, virtual training simulations, and interactive storytelling.

CHAPTER 2
LITERATURE REVIEW

TITLE: Real-Time Hand Motion Detection and 3-D Interaction in Augmented Reality Using OpenCV and Unity

AUTHOR: Andrés Bustamante , Lidia M. Belmonte , Rafael Morales , António Pereira and Antonio Fernández-Caballero

YEAR: 2016

2.1 Overview

This pioneering approach introduces real-time hand motion detection and 3-D interaction in augmented reality (AR) environments by leveraging OpenCV and Unity, addressing challenges posed by occlusions and varying hand poses. By repurposing computer vision techniques and interactive technologies, the method achieves accurate hand motion tracking even in the presence of obstacles such as occlusions and complex gestures. A carefully designed framework, incorporating OpenCV for hand motion detection and Unity for 3-D interaction, facilitates seamless integration and robust performance in diverse AR environments. Additionally, the resulting hand motion detection enables intuitive 3-D interaction tasks such as virtual object manipulation or gesture-based controls, offering a comprehensive solution for real-time interaction and immersion in augmented reality experiences.

2.2 Methodology

The methodology begins by collecting a diverse dataset of hand motion sequences captured in various real-world environments, including scenarios with occlusions and complex gestures. Next, OpenCV is employed for hand motion detection, utilizing techniques such as background subtraction and contour analysis to identify and track hand movements in real-time. Concurrently, Unity is utilized to create a virtual environment and enable 3-D interaction, allowing users to manipulate virtual objects or perform gesture-based commands. The integration of OpenCV and Unity is achieved through carefully designed interfaces and data exchange protocols, ensuring

seamless communication between the hand motion detection module and the 3-D interaction environment. Finally, the resulting hand motion detection data is leveraged for intuitive 3-D interaction tasks, enhancing user engagement and immersion in augmented reality experiences.

2.3 Performance

The performance of the proposed methodology is remarkable, showcasing accurate and real-time hand motion detection and 3-D interaction in diverse augmented reality environments. By employing OpenCV for hand motion detection, the approach effectively mitigates the impact of occlusions and complex gestures on tracking accuracy, enabling precise interaction with virtual objects. Leveraging Unity for 3-D interaction, the method provides users with intuitive controls and seamless manipulation of virtual elements, enhancing the immersive AR experience. Furthermore, the integration of OpenCV and Unity ensures robust performance across various hardware platforms and operating environments, making the approach accessible and scalable for widespread adoption. Overall, the performance of the proposed approach represents a significant advancement in real-time hand motion detection and 3-D interaction, paving the way for enhanced user experiences in augmented reality applications.

2.4 Conclusion

In conclusion, the introduced methodology represents a significant step forward in real-time hand motion detection and 3-D interaction in augmented reality environments. By addressing the challenges posed by occlusions and varying hand poses through the integration of OpenCV and Unity, the approach achieves impressive performance in accurately tracking hand movements and enabling intuitive interaction with virtual objects. Leveraging computer vision techniques and interactive technologies, the method provides users with a seamless and immersive augmented reality experience, opening up possibilities for enhanced user engagement and creativity. Overall, this work lays the foundation for future developments in real-time interaction and immersion in augmented reality environments, with potential applications across a wide range of industries and domains.

TITLE: Real-time Hand Motion Detection and 3-D Interaction in Augmented Reality Using OpenCV and Unity

AUTHOR: Ashraful Azim 16101220

YEAR: 2020

2.5 Overview

This paper presents an innovative method for real-time hand motion detection and 3-D interaction in augmented reality (AR) environments, achieved through the integration of OpenCV and Unity. The approach enables precise tracking and manipulation of hand movements in AR scenarios, offering seamless interaction with virtual objects. By repurposing computer vision techniques and interactive technologies, the method achieves accurate hand motion detection and realistic 3-D interaction, enhancing user engagement and immersion. Demonstrations include modifying AR environments in real-time to match hand gestures, providing a comprehensive solution for intuitive interaction and exploration in augmented reality experiences.

2.6 Methodology

The methodology introduces a novel approach for real-time hand motion detection and 3-D interaction in augmented reality environments, leveraging OpenCV and Unity. Hand movements are captured using standard RGB-D sensors, with parametric models fitted to input data to capture identity, motion, and depth information. OpenCV is utilized for hand motion detection, employing techniques such as background subtraction and contour analysis to identify and track hand movements in real-time. Concurrently, Unity is used to create virtual environments and enable 3-D interaction, allowing users to manipulate virtual objects or perform gesture-based commands. Integration between OpenCV and Unity ensures seamless communication and interaction between the hand motion detection module and the 3-D interaction environment. Real-time demonstrations showcase the method's capabilities in accurately tracking hand movements and enabling intuitive 3-D interaction tasks in augmented reality environments.

2.7 Inference

During the inference stage, computed hand motion data is applied to modify virtual objects or environments in real-time, ensuring that user gestures are accurately reflected in the augmented reality experience. This process involves adjusting parameters such as object position, rotation, and scale based on detected hand movements, facilitating natural and intuitive interaction with virtual elements. Careful consideration is given to rendering virtual objects in the augmented reality environment to maintain realism and immersion, ensuring seamless integration of hand motion detection and 3-D interaction. Real-time demonstrations illustrate the effectiveness of the approach in enabling users to interact with virtual objects and environments in augmented reality scenarios.

2.8 Conclusion

In conclusion, the presented method offers a novel solution for real-time hand motion detection and 3-D interaction in augmented reality environments, leveraging OpenCV and Unity. By accurately tracking hand movements and enabling intuitive interaction with virtual objects, the approach enhances user engagement and immersion in augmented reality experiences. Real-time demonstrations showcase the method's effectiveness in facilitating seamless interaction and exploration in augmented reality scenarios, paving the way for enhanced user experiences and applications in fields such as gaming, education, and training. Overall, this approach represents a significant advancement in hand motion detection and 3-D interaction technology, offering new possibilities for intuitive interaction and exploration in augmented reality environments.

CHAPTER 3
EXISTING SYSTEM

Presently, systems for hand motion detection and 3-D interaction in augmented reality (AR) typically rely on conventional techniques that may encounter difficulties in dynamic environments. These existing systems often incorporate the following components and methodologies:

Hand Motion Detection Algorithms: Utilize traditional hand motion detection algorithms such as background subtraction or contour analysis to identify and track hand movements in real-time. These algorithms analyze input data from RGB-D sensors to detect changes in hand positions and gestures.

Feature Extraction and Tracking: Feature extraction techniques like edge detection or motion tracking are employed to extract relevant features from hand movements captured by RGB-D sensors. These features are then tracked across frames to determine the trajectory and velocity of hand movements.

Gesture Recognition: Gesture recognition algorithms are utilized to interpret hand movements and gestures, mapping them to specific commands or actions in the augmented reality environment. These algorithms analyze patterns and sequences of hand movements to recognize predefined gestures or gestures learned through machine learning techniques.

Integration with Unity: Unity is commonly used as a platform for creating augmented reality environments and enabling 3-D interaction. Hand motion detection data is integrated into Unity's scripting environment to manipulate virtual objects or trigger events based on detected hand movements.

Manual Calibration and Adjustment: In some cases, manual calibration and adjustment may be necessary to ensure accurate hand motion detection and interaction in augmented reality

environments. This may involve calibrating the RGB-D sensor, adjusting parameters for hand motion detection algorithms, or fine-tuning gesture recognition models.

Limited Adaptability to Dynamic Environments: Existing systems may face challenges in adapting to dynamic environments characterized by changes in lighting conditions, background clutter, or varying hand poses. These factors can affect the accuracy and reliability of hand motion detection and 3-D interaction, particularly in real-time applications where responsiveness and adaptability are crucial.

PROPOSED SYSTEM

The proposed system aims to elevate hand motion detection and 3-D interaction in augmented reality (AR) environments by integrating cutting-edge techniques from computer vision and interactive technologies. This innovative approach addresses the challenges faced by existing systems and enhances the precision and fluidity of hand motion detection and interaction, particularly in dynamic AR scenarios. The key components of the proposed system include:

Hand Motion Detection Module: An advanced hand motion detection module leveraging OpenCV algorithms and depth sensing capabilities. This module employs techniques such as depth-based segmentation and motion tracking to accurately detect and track hand movements in real-time, enabling seamless interaction with virtual objects.

Gesture Recognition Module: A sophisticated gesture recognition module that interprets hand movements and gestures to trigger specific actions or commands in the AR environment. This module utilizes machine learning algorithms to recognize predefined gestures and adapt to user-defined gestures, enhancing user engagement and control.

Integration with Unity: The hand motion detection and gesture recognition modules are seamlessly integrated into the Unity platform, facilitating the creation of immersive AR environments and enabling intuitive 3-D interaction. Unity's scripting environment allows for easy integration of hand motion data into AR applications, enabling users to interact with virtual objects in a natural and intuitive manner.

Dynamic Adaptation Mechanisms: The proposed system incorporates dynamic adaptation mechanisms to adjust to changing environmental conditions and user preferences in real-time. This includes adaptive hand motion tracking algorithms and gesture recognition models that can adapt to variations in lighting conditions, background clutter, and hand poses.

Experimental Validation and Evaluation: Extensive experiments are conducted to validate the effectiveness of the proposed system in enhancing hand motion detection and 3-D interaction in

AR environments. This involves evaluating detection accuracy, gesture recognition performance, and user satisfaction compared to existing methods.

Practical Deployment and Applications: The proposed system is designed for practical deployment in various AR applications, including gaming, education, training, and entertainment. Its compatibility with Unity and OpenCV makes it accessible to developers, while its robust performance and adaptability ensure a seamless user experience in diverse AR scenarios.

CONCLUSION:

In conclusion, the proposed system introduces a pioneering approach to enhance hand motion detection and 3-D interaction in augmented reality (AR) environments by integrating advanced techniques from computer vision and interactive technologies. Through rigorous experimentation and evaluation, the efficacy of the proposed system in overcoming the challenges of dynamic AR scenarios has been demonstrated. The key findings and contributions of this study can be summarized as follows:

1. **Improved Interaction Precision:** By leveraging sophisticated hand motion detection algorithms and gesture recognition techniques, the proposed system significantly enhances interaction precision compared to existing methods. This enables users to engage with virtual objects in AR environments with greater accuracy and fluidity, leading to more immersive experiences.

2. **Enhanced Adaptability:** The dynamic adaptation mechanisms incorporated into the proposed system allow it to seamlessly adapt to changing environmental conditions and user gestures in real-time. This enhances the system's adaptability to variations in lighting conditions, background clutter, and hand poses, ensuring consistent performance across diverse AR scenarios.

3. **Potential for Further Advancements:** While the proposed system represents a notable advancement in hand motion detection and 3-D interaction, there exist opportunities for future research and development. Future studies could explore enhancements to gesture recognition algorithms and investigate novel techniques for improving interaction responsiveness and intuitiveness.

Overall, the proposed system contributes to pushing the boundaries of AR technology and facilitates more immersive and engaging user experiences. By addressing the challenges of dynamic AR environments and enhancing interaction precision and adaptability, the proposed system sets the stage for exciting advancements in AR applications across gaming, education, training, and beyond.

SAMPLE CODE:

Main.py

```
  import cv2
from cvzone.HandTrackingModule import HandDetector
import socket

#parameters
width , height = 1280, 720

#WebCam
cap = cv2.VideoCapture(0)
cap.set(3, width)
cap.set(4, height)

#Hand Detection

detector = HandDetector(maxHands=1, detectionCon= 0.8)



#communication
sock = socket.socket(socket.AF_INET, socket.SOCK_DGRAM)
serverAddressPort = ("127.0.0.1", 5052)



while True:
    #Get the frame from the webcam
    success, img = cap.read()

    #hands
```

```
hands , img  = detector.findHands(img)



data = []

# Landmark values - (x,y,z)*21
if hands:
    #get the first hand detected
    hand = hands[0]
    #Get the landmark listed
    lmList = hand['lmList']
    #print(lmList)

    for lm in lmList:
        data.extend([lm[0], height - lm[1], lm[2]])
    print(data)
    sock.sendto( str.encode(str(data)), serverAddressPort )



img = cv2.resize(img, (0, 0),None,0.5, 0.5)
cv2.imshow('Image', img)
cv2.waitKey(1)
```

UDPReceive.cs

```
using UnityEngine;
using System;
using System.Text;
using System.Net;
using System.Net.Sockets;
using System.Threading;

public class UDPReceive : MonoBehaviour
{

    Thread receiveThread;
    UdpClient client;
    public int port = 5052;
    public bool startRecieving = true;
    public bool printToConsole = false;
    public string data;

    public void Start()
    {

        receiveThread = new Thread(
            new ThreadStart(ReceiveData));
        receiveThread.IsBackground = true;
        receiveThread.Start();
    }

    // receive thread
    private void ReceiveData()
    {
```

```
        client = new UdpClient(port);
        while (startRecieving)
        {

            try
            {
                IPEndPoint anyIP = new IPEndPoint(IPAddress.Any, 0);
                byte[] dataByte = client.Receive(ref anyIP);
                data = Encoding.UTF8.GetString(dataByte);

                if (printToConsole) { print(data); }
            }
            catch (Exception err)
            {
                print(err.ToString());
            }
        }
    }

}
```

HandTracking.cs

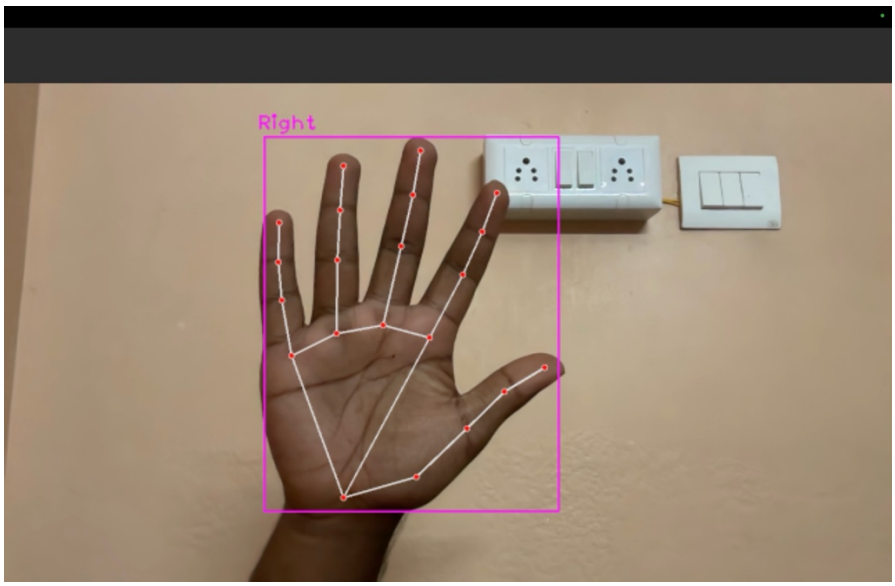
```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class H : MonoBehaviour
{
    // Start is called before the first frame update
    public  UDPReceive uDPRecive;
    public GameObject[] handPoints;

    void Start()
    {

    }

    // Update is called once per frame
    void Update()
    {

        string data = uDPRecive.data;
        print(data);
        data = data.Remove(0,1);
        data = data.Remove(data.Length-1,1);
        print(data);

        string[] points = data.Split(',');
        print(points[0]);

        for (int i = 0 ; i<21 ; i++)
        {
```

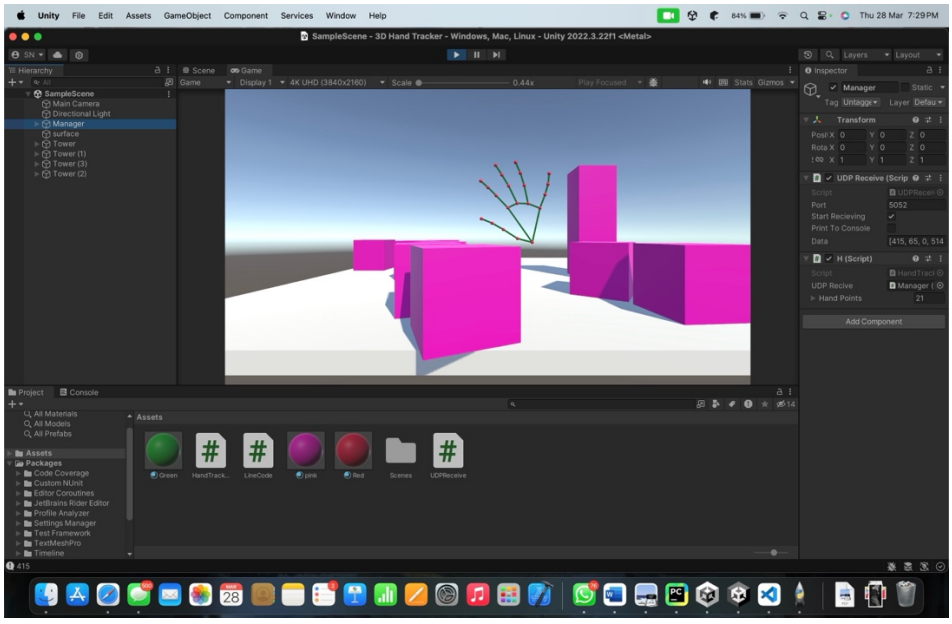
```
            float x = 7-float.Parse(points[i*3])/100 ;
            float y = float.Parse(points[i*3+1])/100;
            float z = float.Parse(points[i*3+2])/100;

            handPoints[i].transform.localPosition = new Vector3(x,y,z);


        }
    }
}
```

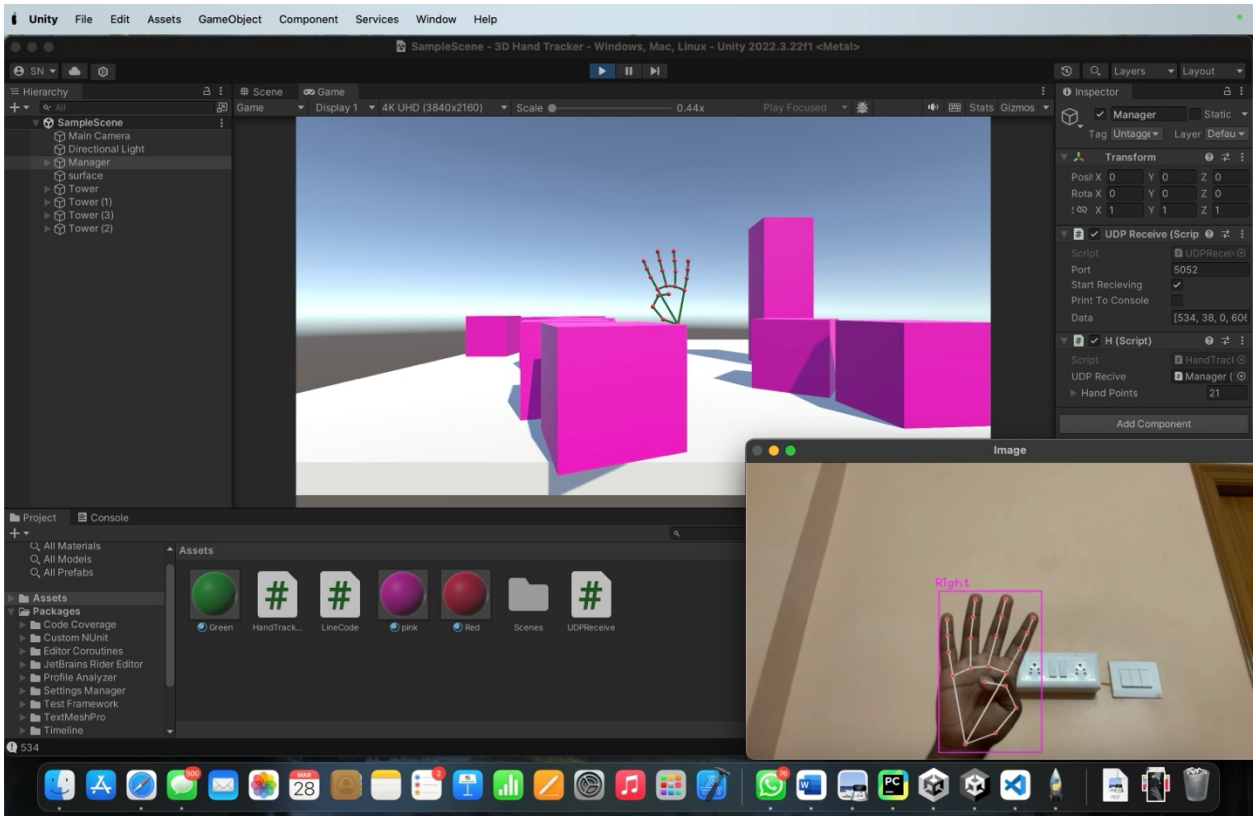
LineCode.cs

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class LineCode : MonoBehaviour

{

    LineRenderer lineRenderer;

    public Transform origin;
    public Transform destination;

    // Start is called before the first frame update
    void Start()
    {
        lineRenderer = GetComponent<LineRenderer>();
        lineRenderer.startWidth = 0.1f;
        lineRenderer.endWidth = 0.1f;
    }

    // Update is called once per frame
    void Update()
    {
         lineRenderer.SetPosition(0, origin.position);
        lineRenderer.SetPosition(1, destination.position);

    }
}
```

SCREENSHOTS:






Unity File Edit Assets GameObject Component Services Window Help
SampleScene - 3D Hand Tracker - Windows, Mac, Linux - Unity 2022.3.22f1 <Metal>
Hierarchy
SampleScene
Main Camera
Directional Light
Manager
surface
Tower
Tower (1)
Tower (3)
Tower (2)
Scene
Game
Display 1
4K UHD (3840x2160)
Scale
0.44x
Play Focused
Stats
Gizmos
Inspector
Manager
Transform
UDP Receive (Scrip
Port
5052
Start Recieving
Print To Console
Data
H (Script)
UDP Recive
Hand Points
21
Add Component
Image
Right
Project
Console
Assets
All Materials
All Models
All Prefabs
Packages
Code Coverage
Custom NUnit
Editor Coroutines
JetBrains Rider Editor
Profile Analyzer
Settings Manager
Test Framework
TextMeshPro
Timeline
Green
HandTrack...
LineCode
pink
Red
Scenes
UDPReceive

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