Introduction & Weekly Work Update

SenseXR: Smart Clothing for Collaborative Experiences in XR

Research Project - ***Creative Interfaces Lab***

Semester V

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Introduction - Literature Review - Problem Statement - Implementation

INTRODUCTION

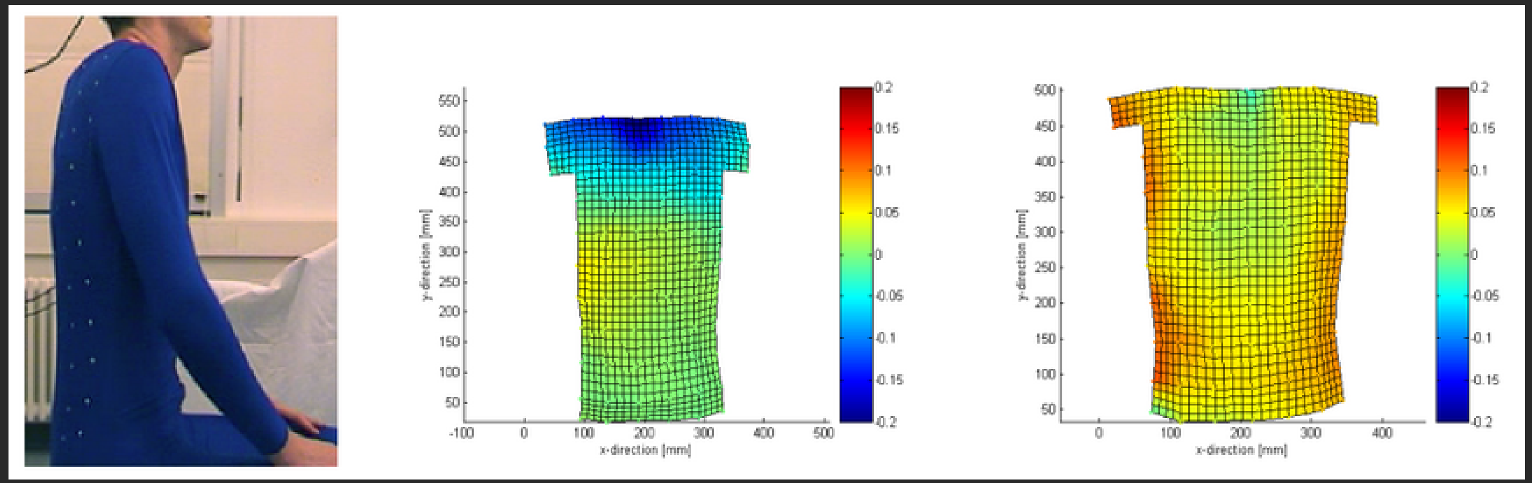
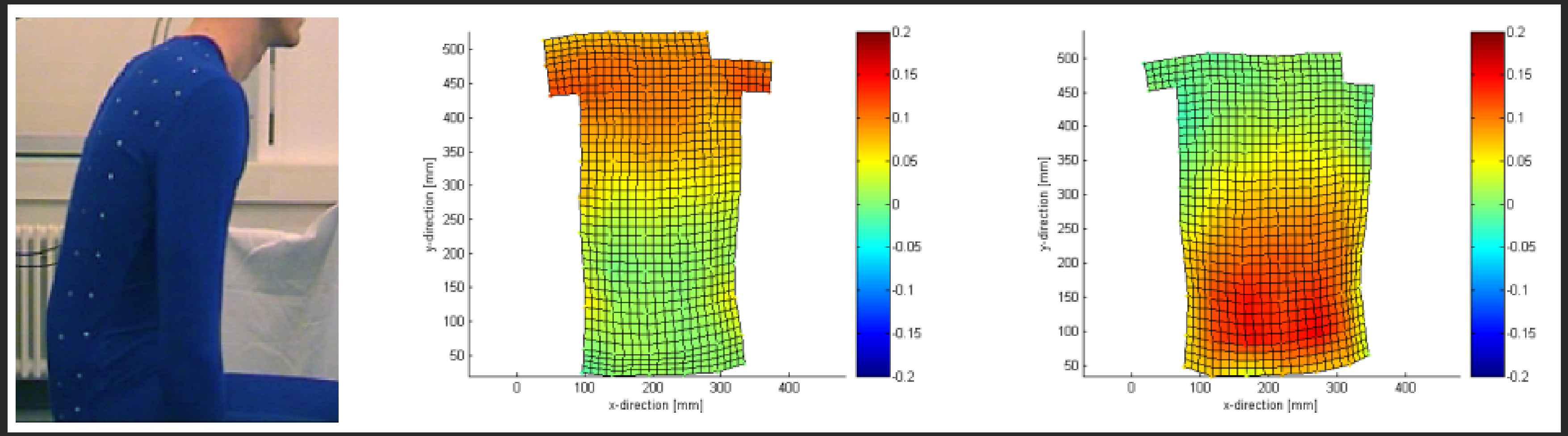
A brief overview

One of the critical challenges in the XR domain is enhancing the immersive experience while simultaneously enabling collaboration among users. Immersion in a virtual or augmented world can sometimes isolate individuals from their immediate physical surroundings and peers. This is where our smart jacket, SenseXR, comes into play.

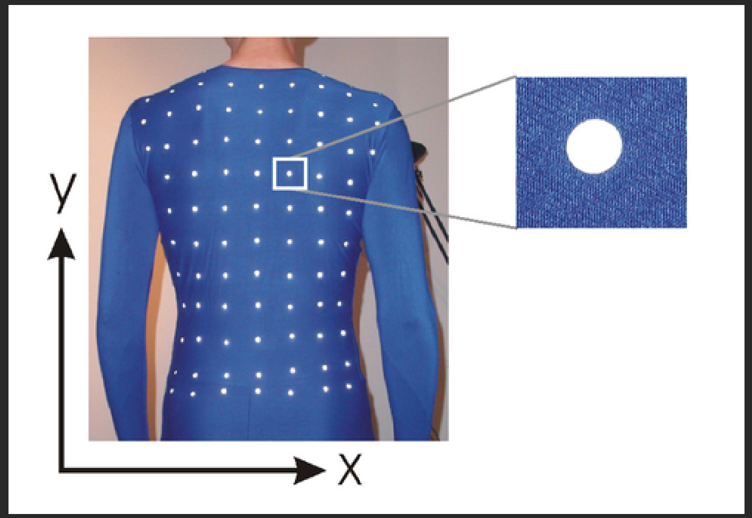
Over the next few weeks, we hope to gain a better understanding of XR using Unity. We would be exploring various candidate sensors to be integrated into our jacket. We'd also be studying computer vision methods to better identify the user and incorporate them in a virtual environment

LITERATURE REVIEW

Body Posture Detection Using Strain Sensitive Clothing

Using marker positions to estimate strain data



Reflective markers

They use an array of reflective markers placed on a tight-fitting suit. The elastic suit morphs according to the users movements. The method was based on measurements using an optical motion tracking system. The markers would shift with respect to each other as the user moves.

Pros: Reflective markers offer high accuracy when reproduced.

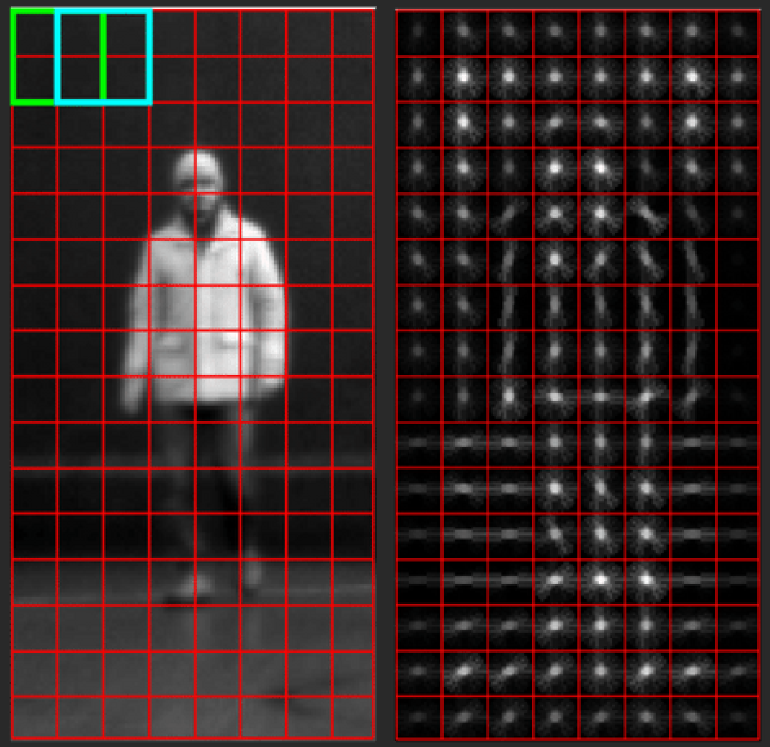
Cons: Visual feed means that markers are prone to occlusion.

LITERATURE REVIEW

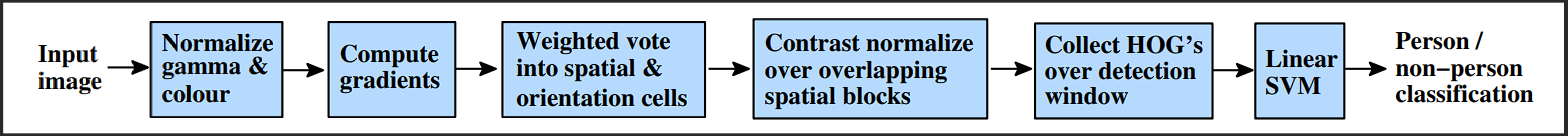
Histograms of Oriented Gradients for Human Detection

This paper studies feature sets for visual object recognition, in linear SVM based human detection. They cover different methods based on evaluating well-normalized local histograms of image gradient orientations in a dense grid. The basic idea is that local object appearance and shape can often be characterized rather well by the distribution of local intensity gradients.

In addition to studying HOG descriptors, they present a better alternative to the MIT pedestrian database, providing 1800+ annotated human images with a wide range of postures and backgrounds.



HOG grid



Pros: Larger richly annotated dataset has been provided for human detection.

Cons: Overlapping in noisy data for large datasets can affect linear SVM method.

LITERATURE REVIEW

An Approach for Detecting Human Posture by Using Depth Image

The conventional method for human pose estimation is through 2D RGB images, where it is difficult to extract the target object from the background. This paper discusses a depth-based approach using depth images obtained from Kinect. They use the head model to match and locate the human position by edge extraction method followed by template matching and human detection.

HOG features are then extracted from the depth images to get their corresponding characteristic vectors. For the next step, Generalized Regression Neural Network classifier is used to extract the character based on the depth of region. The GRNN classifier tells us if the given character is sitting or standing.

Pros: Better character extraction due to depth images.

Cons: Poor accuracy for sitting posture due to interference from chairs.

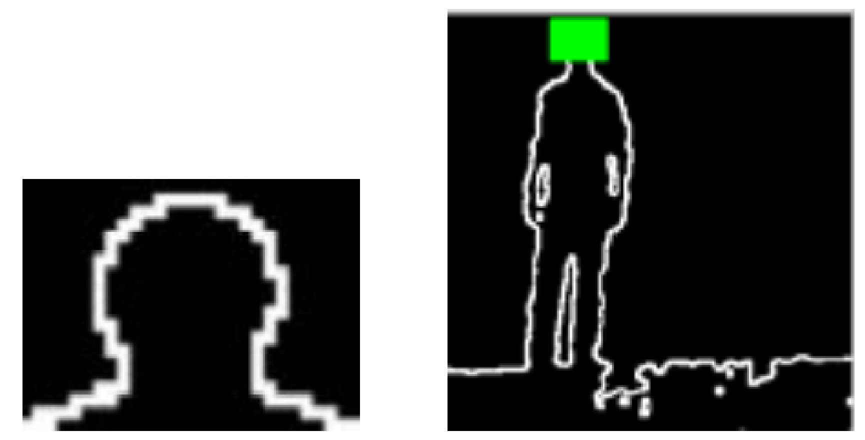


FIGURE IV. HEAD MATCHING

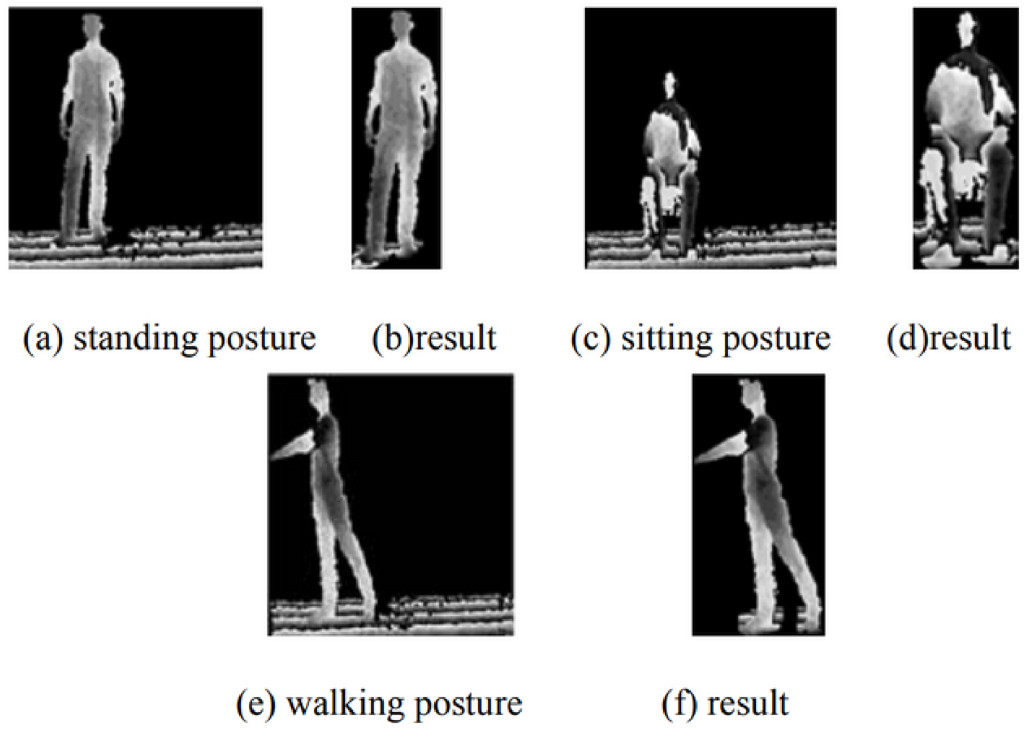


FIGURE VIII. CHARACTER EXTRACTION RESULTS

PROBLEM STATEMENT

Target

Our objective is to implement a collaborative experience in real-time where two or more users can experience a shared virtual world

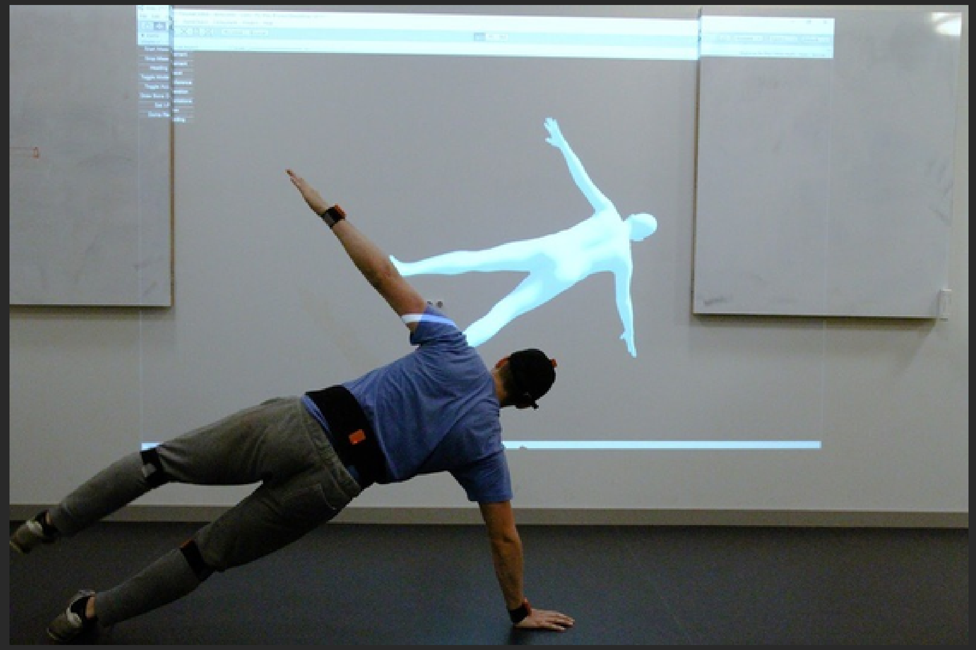
We hope to attain this through either of these two approaches:

1. Make a Jacket with flex sensors and IMUs, coupled with an RGB camera, using the multi-modal data to create a real-time 3D human body in Unity.
2. Design a Jacket with strategically placed markers having unique and identifiable patterns for easy tracking. Now using CV techniques to track the movements and orientation, estimating and exporting the real-time pose of the user.

The resulting model can be then streamed to a viewer as an augmented reality experience through their headset.

●●● IMPLEMENTATION

Wearables with integrated sensors and LilyPad controller



This project involves creating a real-time body posture visualization using wearables equipped with integrated sensors and a LilyPad controller, all integrated with Unity XR.

Sensor Implementation

We will be using wearable devices like that can track and capture data related to the body's movements and positions. These sensors provide valuable information about how a person's body is positioned and oriented in space.

UNITY XR Implementation

we process this raw sensor data using UNITY Humanoid extension to make sense of it. This involves converting it into a format that Unity can understand and use. It will be the first phase of our Project, which will involve creation of a accurate Human posture into unity, and then phase II will involve, animation the posture into real time place, using Augmented Reality.

Pros: Presenting Accurate and Virtual Mixed reality Communication protocol in form XR Video calls

Cons: There might be complications relating to Accurate posture Detection

IMPLEMENTATION

Optical motion capture using RGBD images

Collaborative XR experience can be attained through a combination of CV techniques applied on multi-modal RGBD data. We hope to develop a method to identify the human, by estimating pose and 3D location, through the RGB and Depth cameras and import the model into a remote virtual environment. This would be analogous to video calls, but with added immersion due to the real 3D silhouette of the users being presented in a real/virtual environment.

The framework for this implementation would follow some basic steps:

> Markers on the jacket/suit to aid detection of human silhouette from RGB and Depth images.

> Tracking the pose and movements of the user's silhouette.

> Importing the isolated points from the image, those representing the user, into UNITY

WEEK 3-5 PROGRESS

Topic: SenseXR: Smart Clothing for Collaborative Experiences in XR

MODELLING AND SIMULATION - IMAGE PROCESSING TECHNIQUES - FRAMEWORK

MODELLING AND SIMULATION

Learning Unity and working with Open3D & OpenCV

Learning Unity

1. 3D Model Importers: OBJ (.obj): The Wavefront OBJ file format is a simple and widely supported format for 3D models. Unity has a built-in OBJ Importer.
2. Point Cloud Importers: PCD (.pcd): Point Cloud Data file, commonly used by the Point Cloud

Python OpenCV and Open3D libraries

While we talk about modeling and using point cloud datasets, OpenCV and Open3D are the two most useful libraries whose features we used.

1. **Point Cloud Visualization**: OpenCV has a visualization module (cv2.viz) that can be used to visualize 3D data, including point clouds. This module allows you to create interactive 3D visualizations of point clouds.
2. **3D Pose Estimation:** OpenCV includes functions for camera calibration and pose estimation, which can be applied to estimate the pose of a 3D object or point cloud relative to the camera.
3. Depth Map Generation: OpenCV includes algorithms for depth map generation from stereo images. The generated depth maps can be used as input for creating or refining point cloud data.

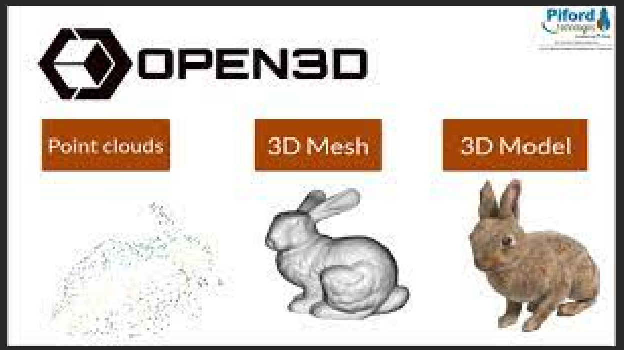
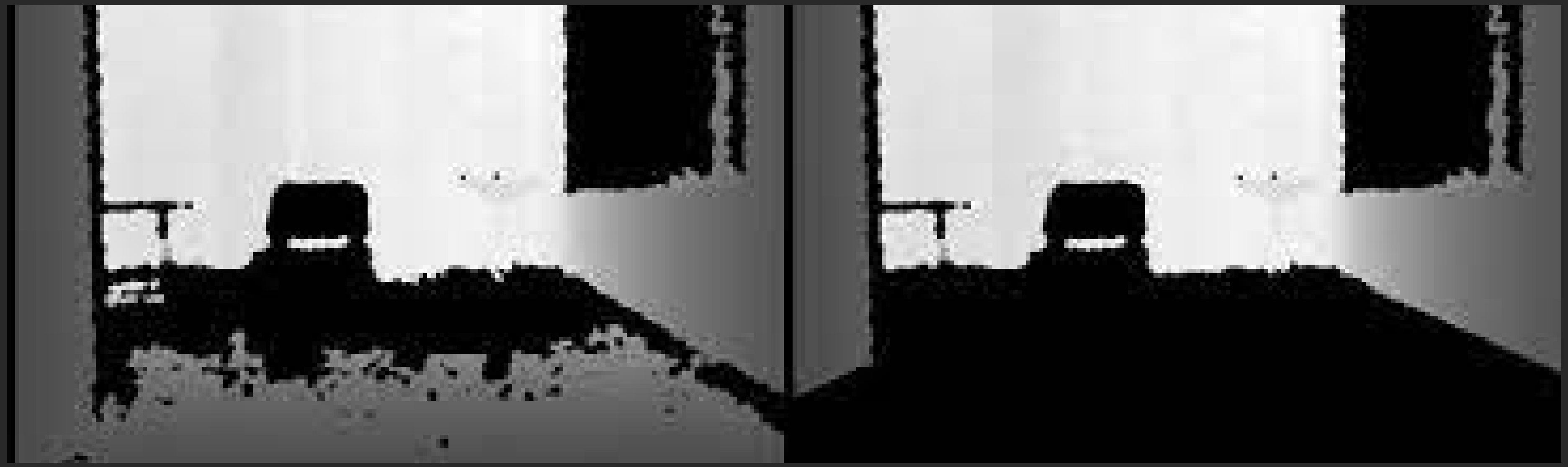


IMAGE PROCESSING TECHNIQUES

JPEG PLY

Working on Depth Images

1. **Usage of Depth Images:-** We learn how depth images work and what data they have during Week -3. Now we took some random depth image datasets, where some obj and ply files were there, and tried various techniques on them.
2. Application of computer Vision Techniques:-
    a. Projecting 3D Points to 2D Image
    b. Depth Image Creation
    c. RGB Image Creation
    d. Depth Image FIltering
    e. DBSCAN Clustering
    f. Sillhouette Extraction



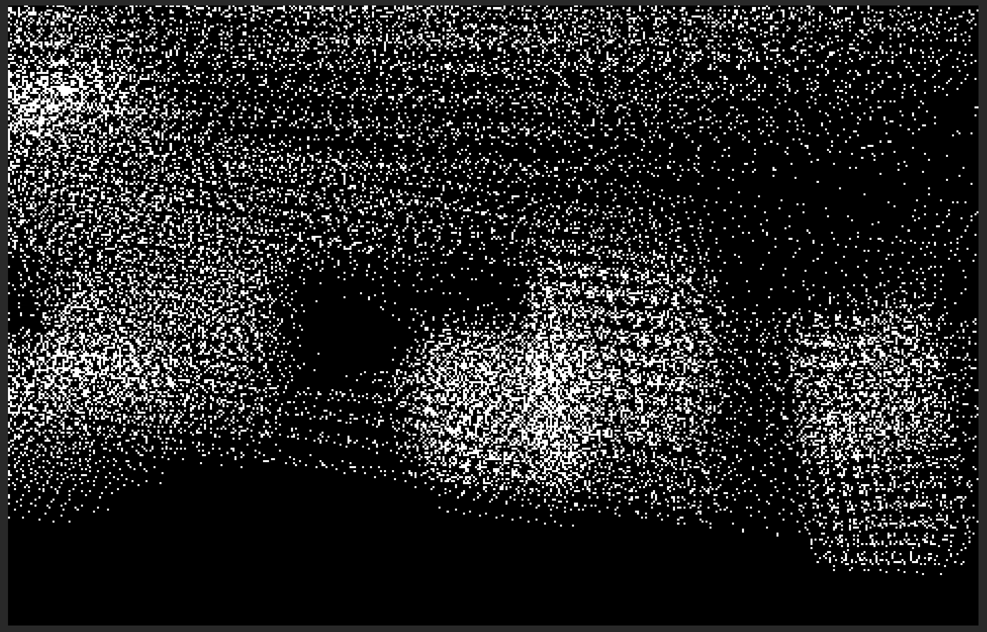
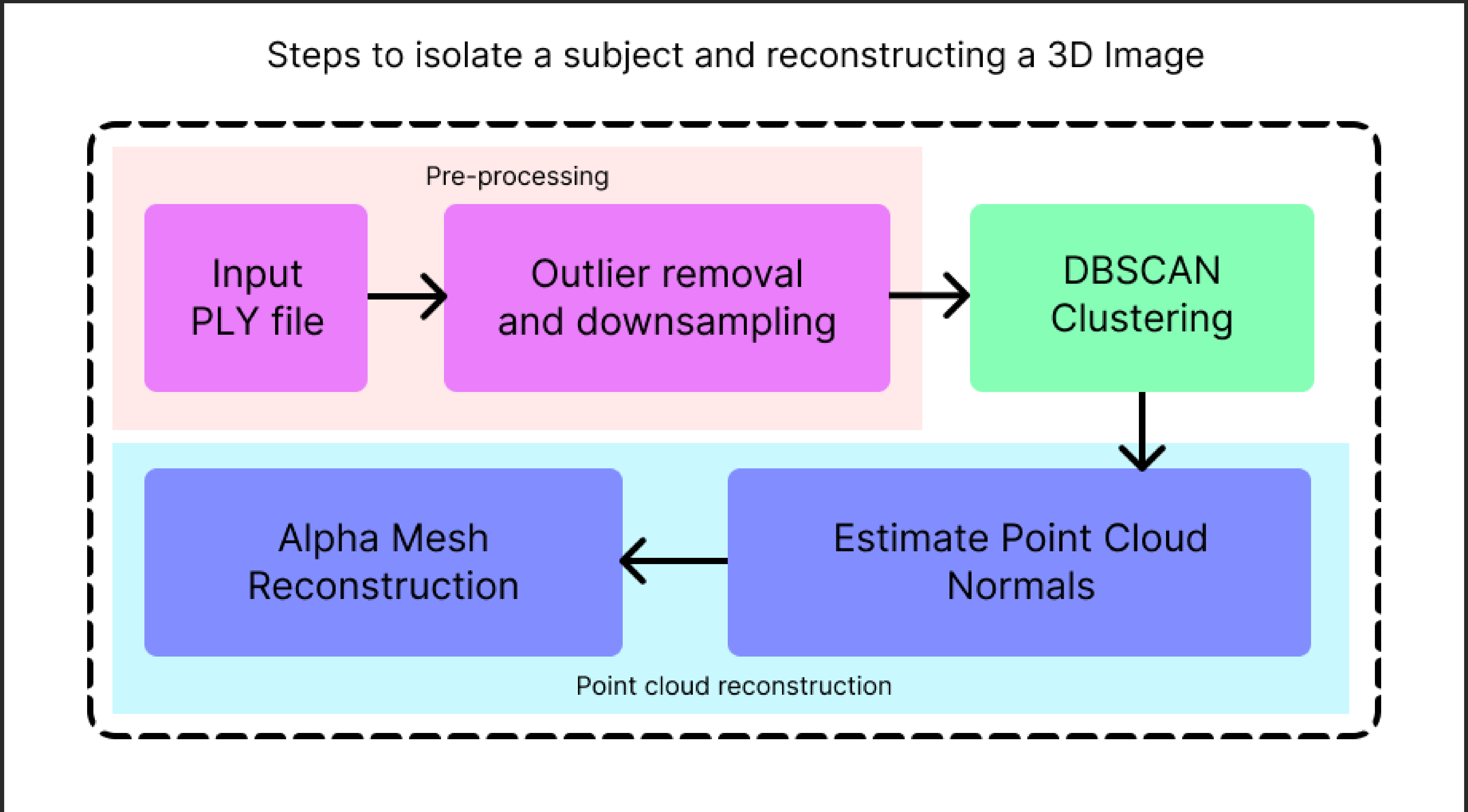


IMAGE PROCESSING TECHNIQUES

FRAMEWORK

Till week 5, we were exploring a variety of techniques and were a bit confused about what techniques should be applied and how an effective procedure should be followed.

But after week 5, we applied some permutations and combinations of feature extraction techniques, and the final output which for us involved these techniques.



WEEK 6-7 PROGRESS

Topic: SenseXR: Smart Clothing for Collaborative Experiences in XR

IMPLEMENTATION

IMPLEMENTATION

Working with PLY files

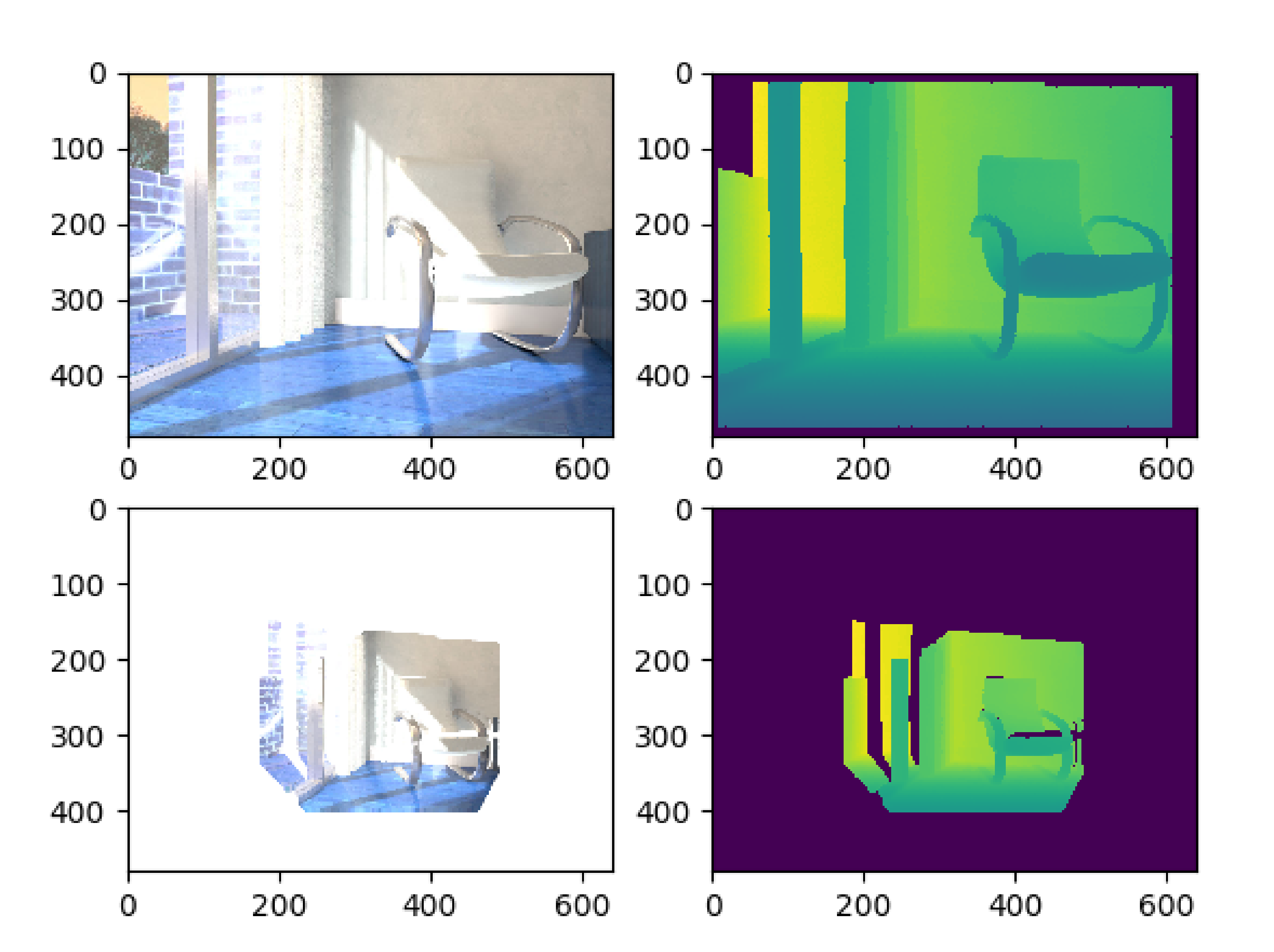


Image credits: walkalone31 (GitHub)

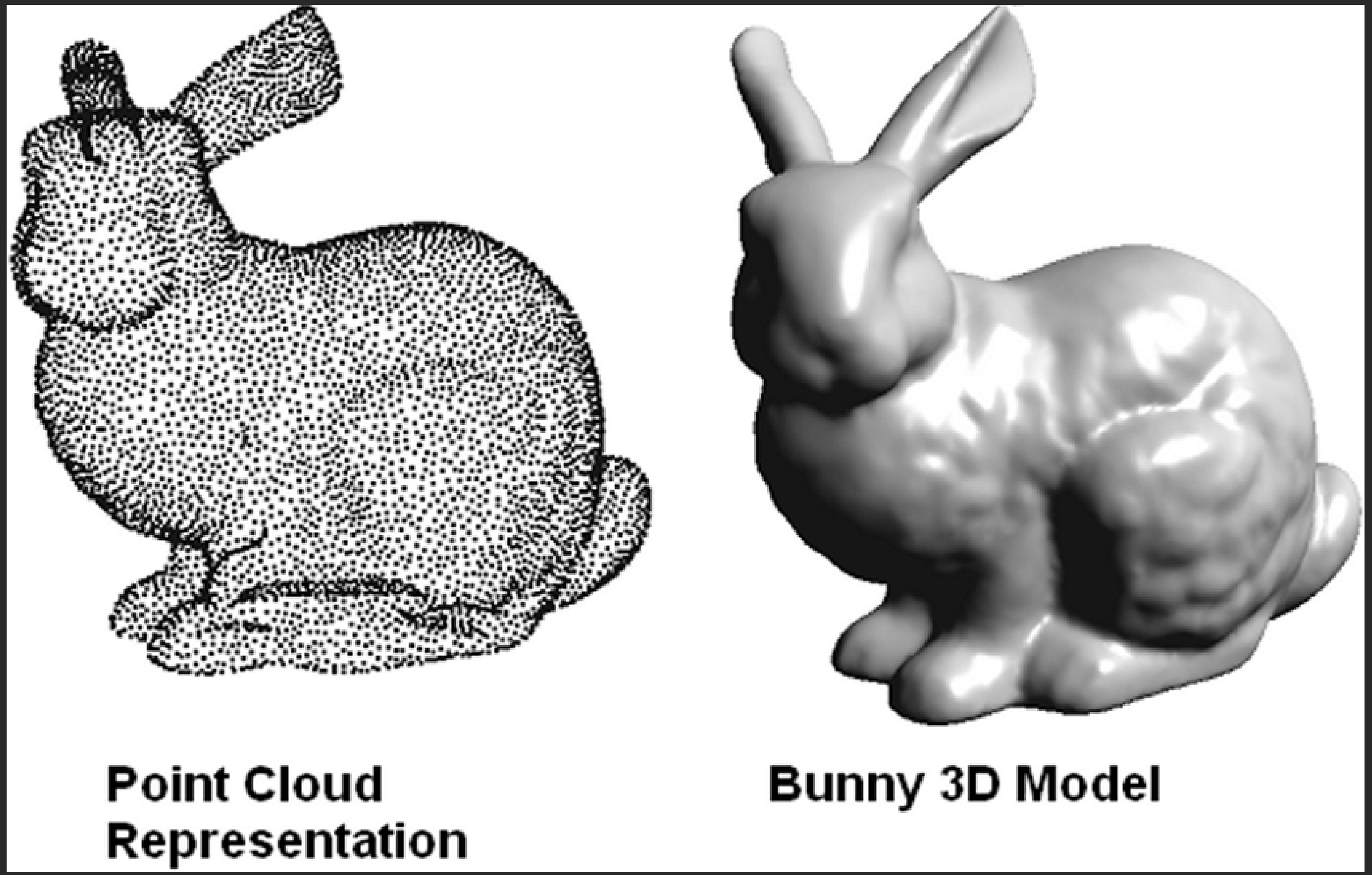
A projection method is applied to the PLY file to project the 3D points onto a 2D plane, simulating how the scene would be captured by a camera. The resulting 2D coordinates are then mapped to pixel values based on depth information, generating a depth image where pixel values represent distances from the camera.

In order to convert a depth image back to a PLY file, depth values are extracted from the image, and using the original camera projection model, 2D coordinates are converted back into 3D points in space. The reconstructed 3D points can then be stored to a PLY file.

All the above steps can be accomplished using lihbraries like Open3D and PCL (Point Cloud Library)

IMPLEMENTATION

Working with PLY files

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property float y
property float z
property float nx
property float ny
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property uchar red
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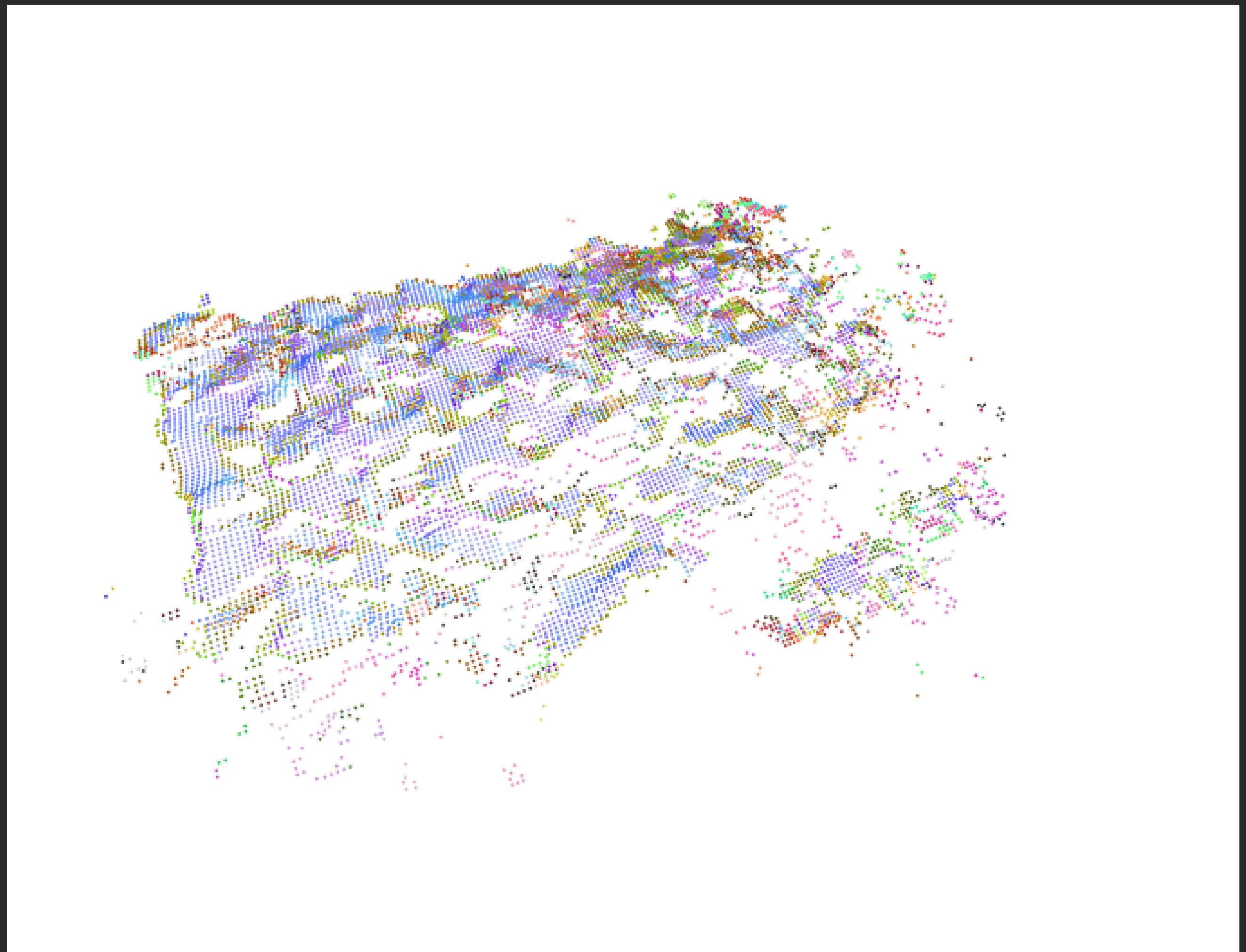
PLY file header and contents

IMPLEMENTATION

Working with PLY files



Point cloud image of a subject's torso

Front view and top view of scatter plot with higher point size

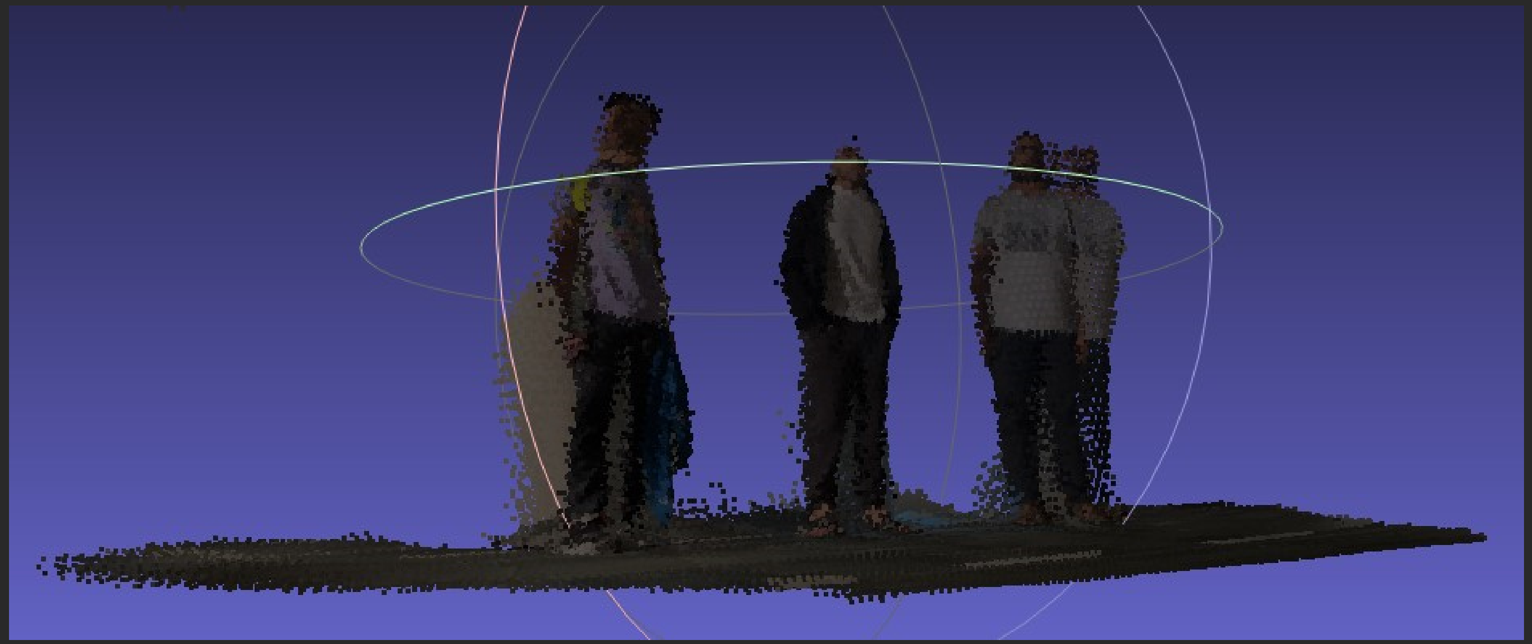
WEEK 8-10 PROGRESS

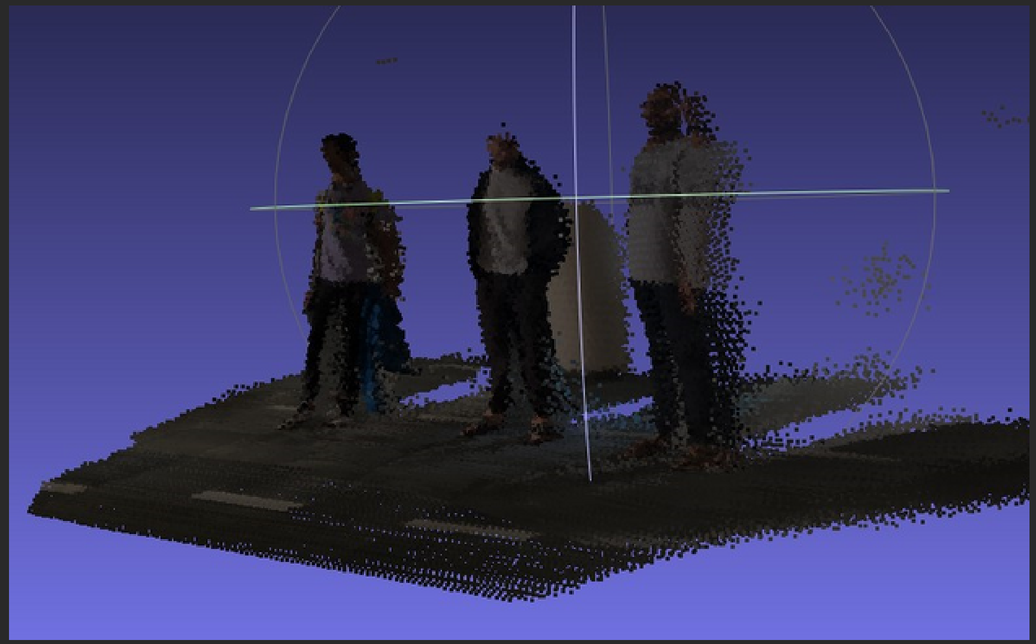
Topic: SenseXR: Smart Clothing for Collaborative Experiences in XR

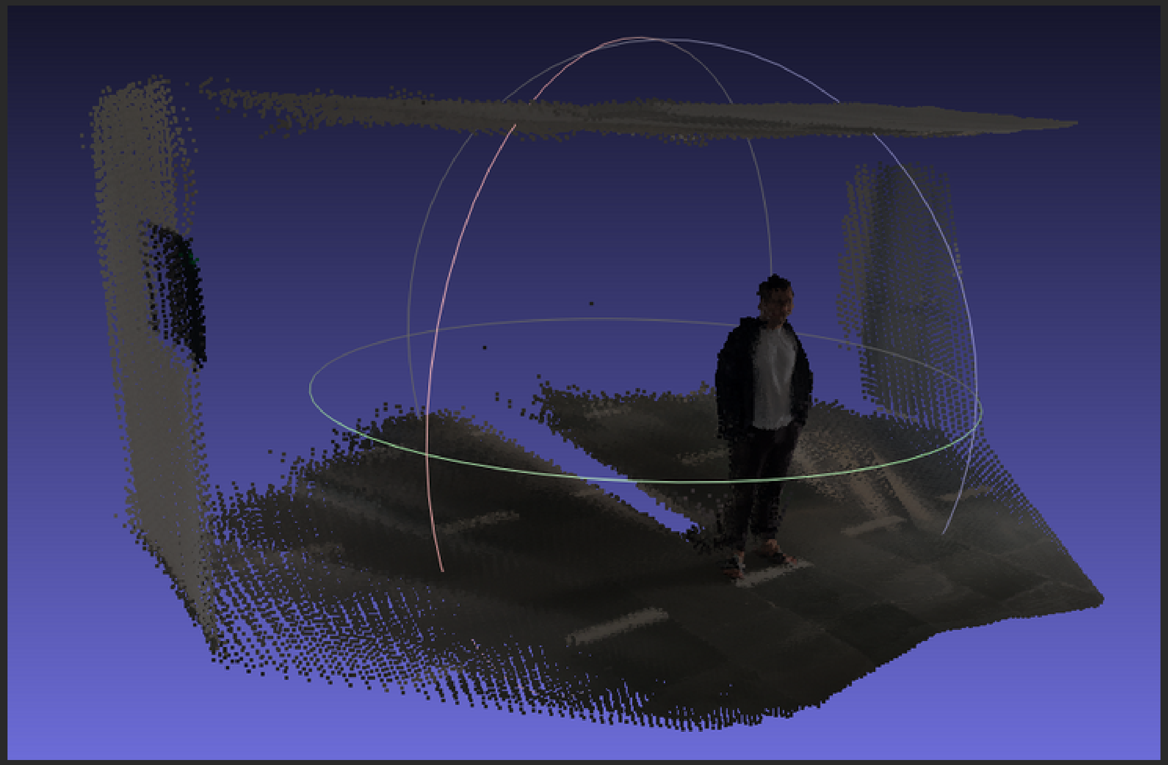
IMPLEMENTATION

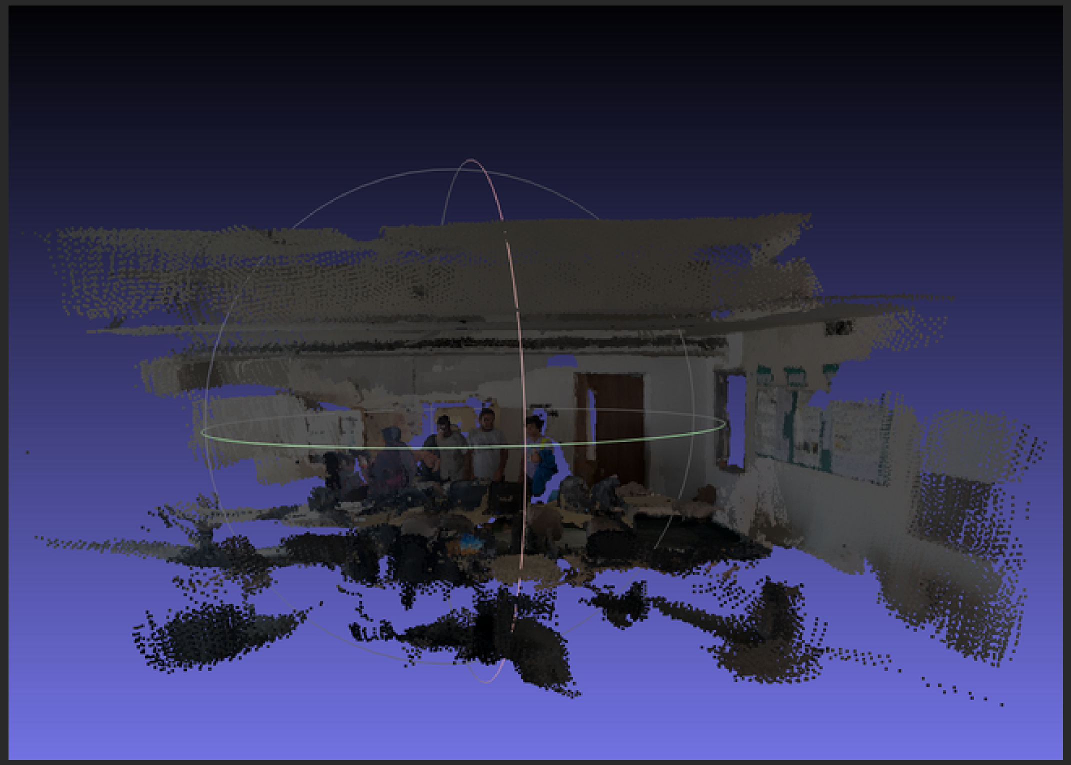
IMPLEMENTATION

LiDAR Images from iPhone 14 Pro LiDAR sensors







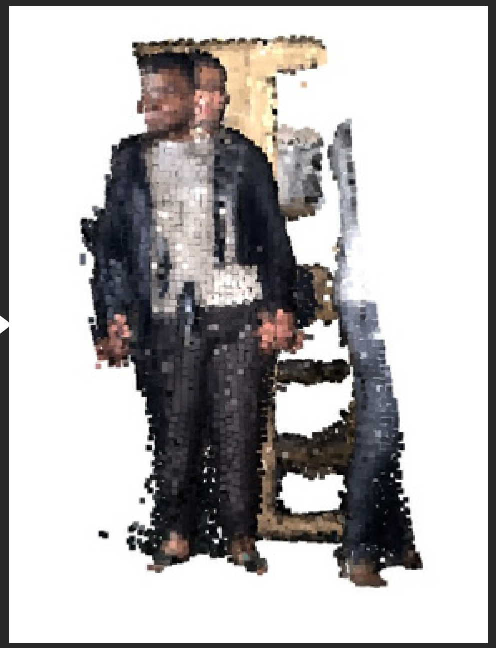


IMPLEMENTATION

Voxel Down-sampling and K-Means Clustering

Voxel downsampling

Clustering



Background Extraction

IMPLEMENTATION

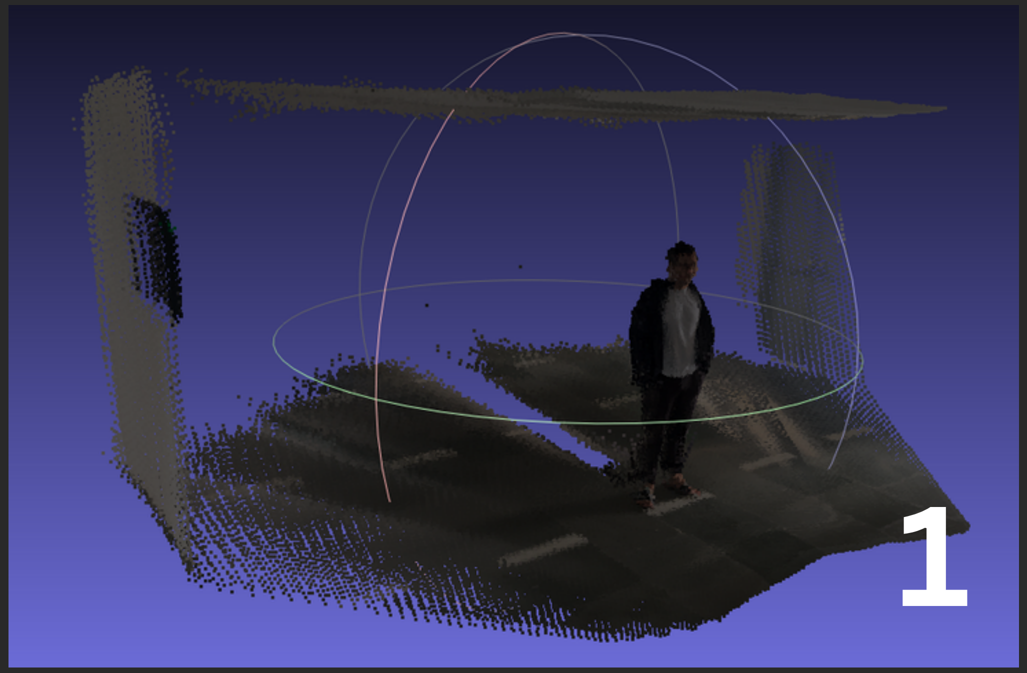
DBSCAN Clustering and mesh reconstruction

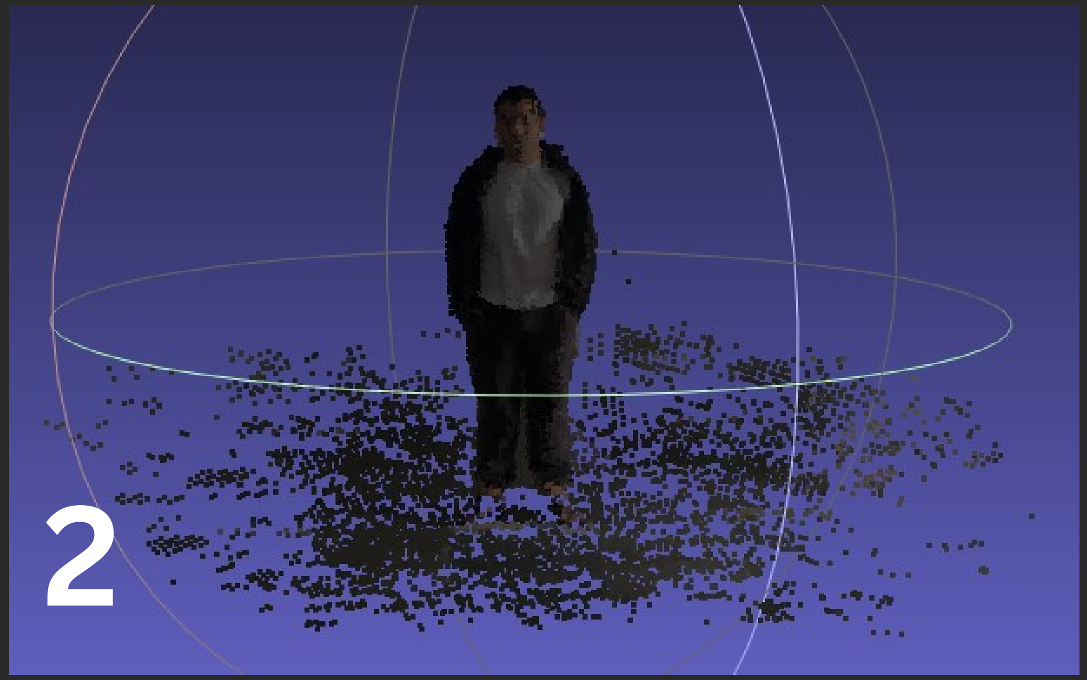
1. Input point cloud with a subject and a background: The image was generated by stitching together multiple point cloud groups with slight adjustments to camrea position

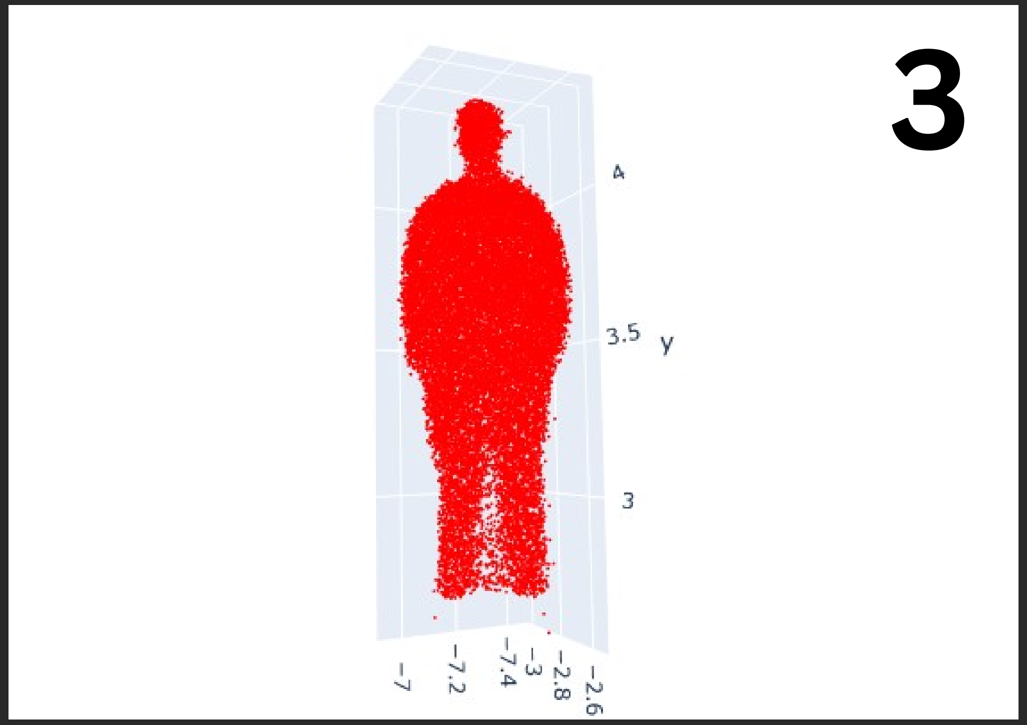
2. Subject and some residual noise after background removal.

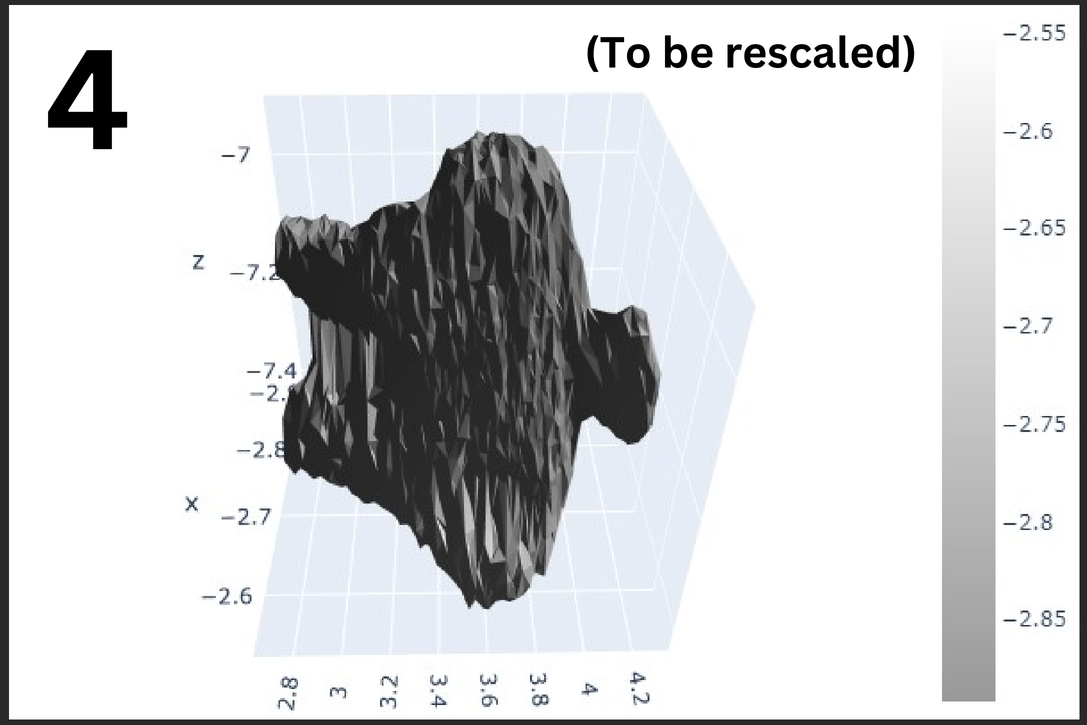
3. Output after DBSCAN clustering.

4. Alpha mesh reconstruction: Point cloud #3 was downsampled, followed by normal estimation step and then alpha mesh reconstruction with alpha = 0.05





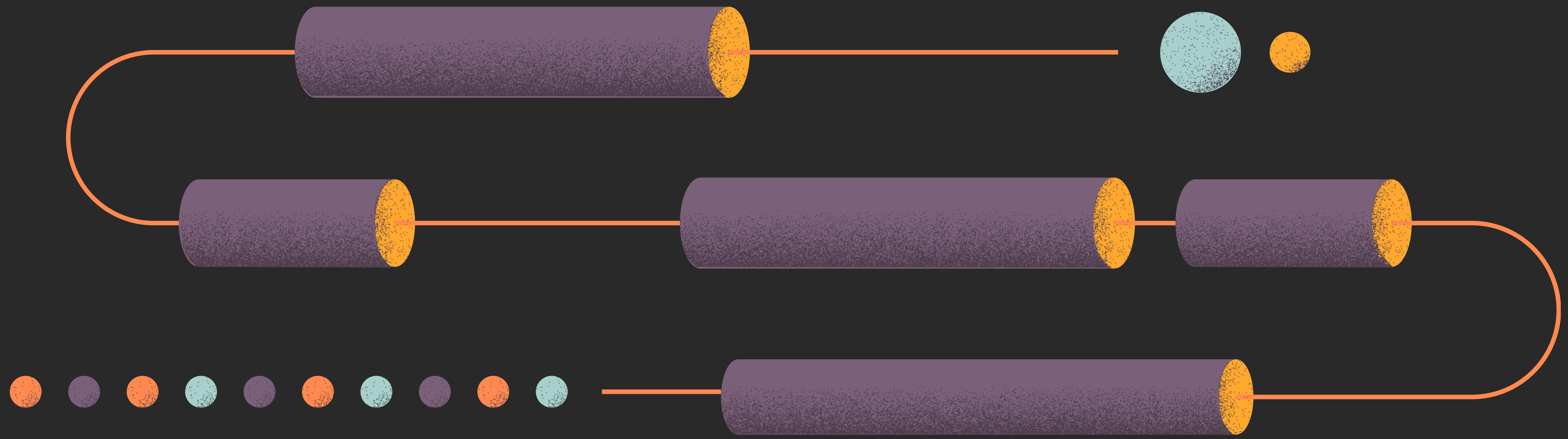




WRAPPING UP

Topic: Object Visualization in Virtual and Mixed Reality

Modelling and Simulation



●●● UNDERSTANDING MIXED REALITY

Learning about MetaQuest 2 VR Headset and its functionalities

Understanding Meta Quest 2:

- We began by thoroughly studying the MetaQuest 2 instruction manual. This comprehensive review allowed us to grasp the device's technical specifications, operational nuances, and optimal use scenarios.
- We gained firsthand experience in navigating its interface, adjusting settings, and optimizing its performance. This practical exposure has been instrumental in bridging the gap between theoretical comprehension and real-world application.

<model-viewer>

gravity sketch™

TESTING ON NEW DATA

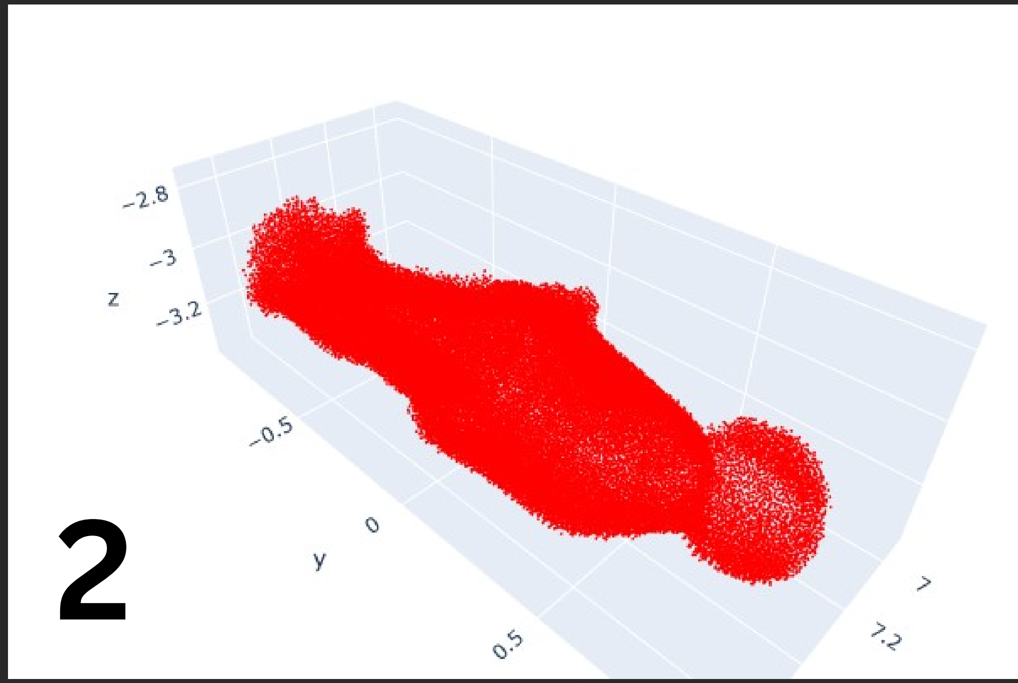
DBSCAN Clustering and mesh reconstruction

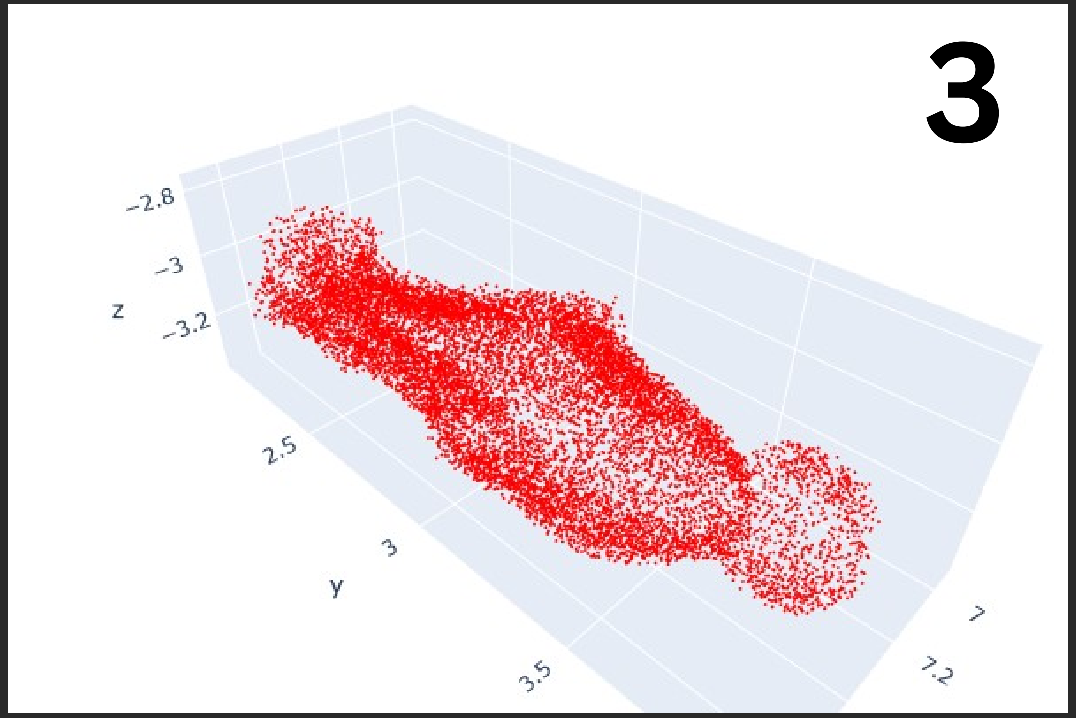
1. Input point cloud with a subject and a background: The full 3D model of the person was obtained using iPhone LiDAR sensor.

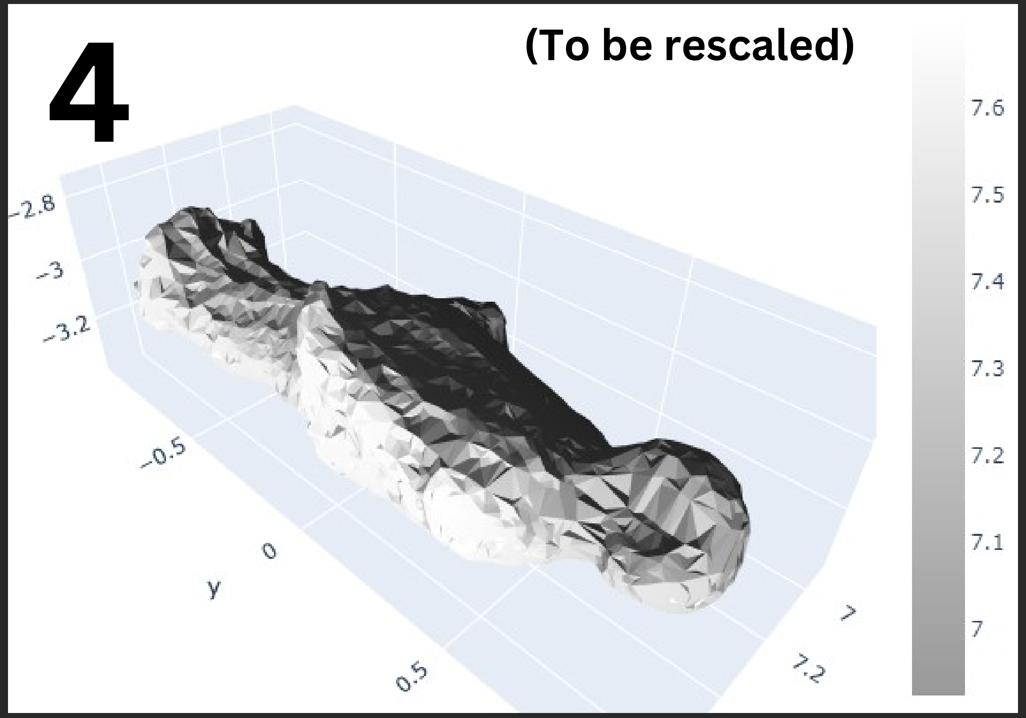
2. First iteration of DBSCAN clustering

3. Down-sampling and second iteration of DBSCAN clustering

4. Alpha mesh reconstruction: Normal estimation step and then alpha mesh reconstruction with alpha = 0.07







Modelling and Simulation

TESTING ON NEW DATA

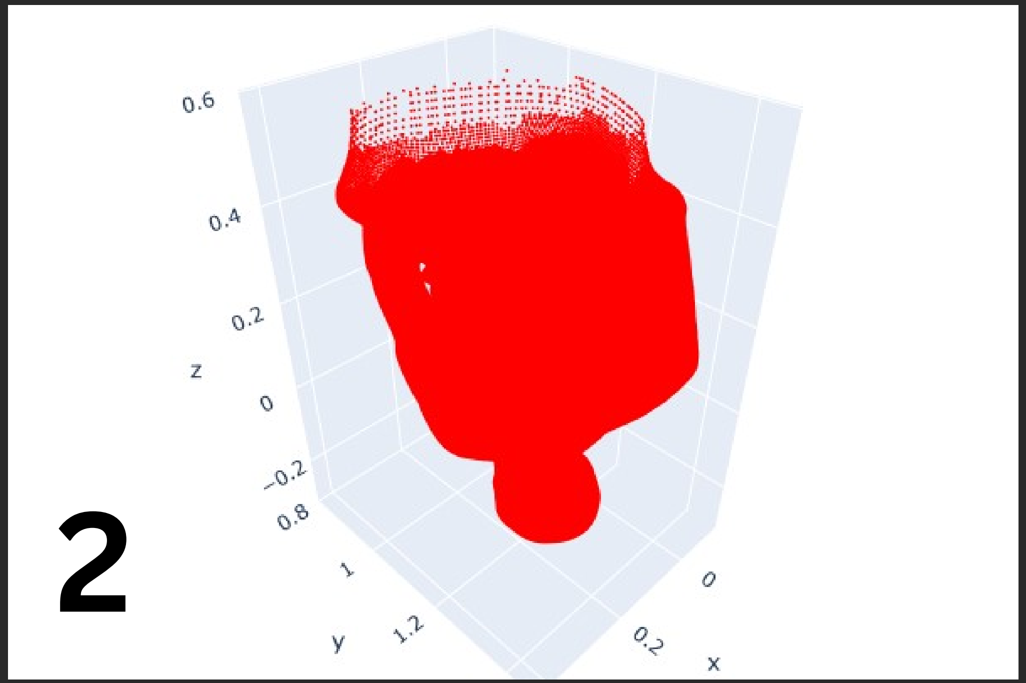
DBSCAN Clustering and mesh reconstruction

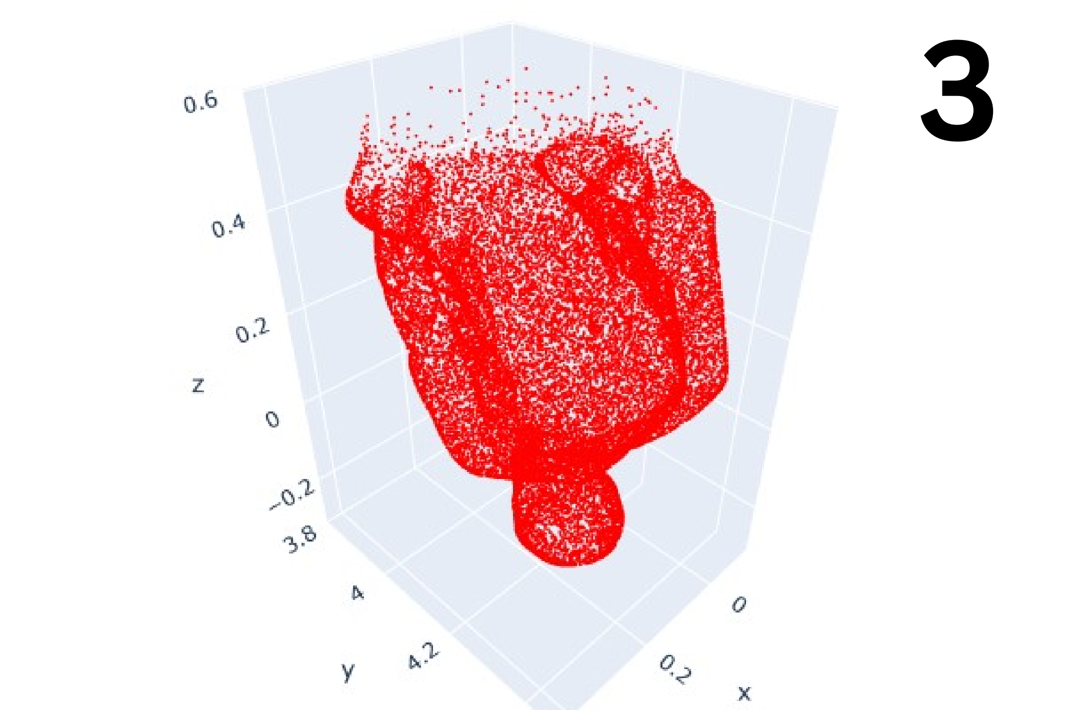
1. Reference image with a subject and a background: The full 3D model of the person was obtained using Kinect RGBD sensor.

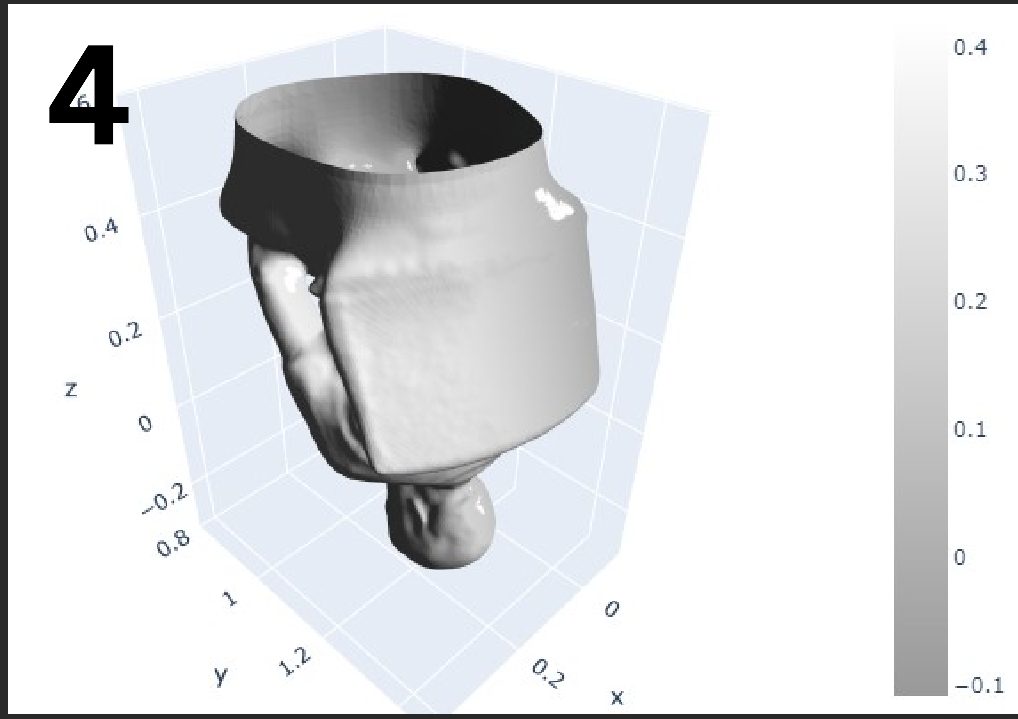
2. First iteration of DBSCAN clustering

3. Down-sampling and second iteration of DBSCAN clustering

4. Poisson mesh reconstruction: Normal estimation step and then Poisson mesh reconstruction with depth = 8







FUTURE WORK

As of now, we are able to retain most of our ideal outputs in the project. Our focus has been on enhancing the capabilities of SenseXR, particularly in the realm of point cloud 3D images, which we have achieved.
Looking ahead, our goal is to seamlessly integrate this technology into everyday use, allowing users to interact with it effortlessly via an iPhone Lidar through a user-friendly graphical interface (GUI).
Furthermore, we are excited about the prospect of extending this project, either as a part of our Bachelor's Thesis Project or independently. We are keen on submitting a paper to the IEEE AR/VR Orlando Conference scheduled for next year, for which we want to continue working on it after this semester.
Please have a look at the poster attached on the next slide.

- **Deep Learning Techniques for Point Cloud Segmentation**
- **Processing 3D files as video/series of OBJs**
- **Improving Mesh Reconstruction**
- **Develop an end-end application for sensing, processing, meshing and visualization**

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March 16-20, 2024