# A Platform for Subjective Quality Assessment in Mixed Reality Environments

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*Abstract*—**3D objects are important components in Mixed Reality (MR) environments as they allow users to inspect and interact with them in a six degrees of freedom (6DoF) system. Point clouds (PCs) and meshes are two common 3D object representations that can be compressed to reduce the delivered data at the cost of quality degradation. In addition, as the end users can move around in 6DoF applications, the viewing distance can vary. Quality assessment is necessary to evaluate the impact of the compressed representation and viewing distance on the Quality of Experience (QoE) of end users. This paper presents a demonstrator for subjective quality assessment of dynamic PC and mesh objects under different conditions in MR environments. Our platform allows conducting subjective tests to evaluate various QoE influence factors, including *encoding parameters*, *quality switching*, *viewing distance*, and *content characteristics*, with configurable settings for these factors.**

*Index Terms*—**Point Clouds, Subjective Test Platform, Quality of Experience, Mixed Reality**

## I. INTRODUCTION

Point Clouds (PCs) are 3D objects comprising a collection of points, each having geometric and texture characteristics. While they can contain a high level of detail, point clouds are hard to capture and often include visual artefacts introduced at some point during the capturing and rendering process. Additionally, transmitting PCs usually requires significantly more bandwidth than regular videos and streaming them with an adaptive streaming approach can lead to quality degradation. Subjective quality assessment of PCs can lead to a better understanding of how consumers of PC content are affected by these distortions.

Several works have explored the subjective quality assessment of PCs in different media. For example, the work in [8] encodes PCs from the 8i Voxelized Full Bodies Database [3] with MPEG Point Cloud Compression (PCC) reference software Test Model Category 2 [4] and then creates 2D videos for these PCs. The videos are played on a 2K resolution screen in subjective tests. The authors discovered that the subjective ratings for volumetric media were generally worse than those for traditional videos.

In a relatively early work, the authors of [1] implemented a PC subjective quality assessment in an Augmented Reality

(AR) scenario, investigating how noise and other distortions affect the viewers of PC content. They highlighted the importance of such an implementation due to the growing popularity of AR devices and applications. The test participants were able to observe and interact with the PCs and were asked to rate different levels of degradation. The authors concluded that the performance of PCs was content-dependent.

To subjectively evaluate the different configurations of a PC, Alexiou *et al.* [2] introduced a toolbox named PointXR. It contains a tool used to determine rendering configurations for the models used in the subjective testing in a Virtual Reality (VR) environment. As part of the development of the tool, they added a "square shader" functionality to the already existing Pcx "Point Cloud Importer/Renderer for Unity" [6]. The authors discovered that the square shader is computationally more efficient than the already existing disk shader from Pcx. Furthermore, the toolbox has subjective testing capabilities in which the test participants can navigate, but not interact, with the objects in a VR space. Notably, the PCs used in this work were not animated but static.

In recent work, Van Damme *et al.* [7] propose a novel in-session quality rating methodology for volumetric video, providing a more accurate assessment as well as avoiding post-study bias. This is made possible through the use of immersive sliders, which are shown above dynamically moving mesh objects and can be used to rate the content on a scale from 1 to 10 (low to high quality). Thus, the user can consume and rate the content within the immersive environment.

Taking inspiration from PointXR [2] and the latter methodology [7], this paper introduces a new platform for subjective quality assessment of PCs in Mixed Reality (MR) environments. In this platform, we implement the rendering formats from PointXR and Pcx to be used with the Microsoft HoloLens 2, a state-of-the-art MR head-mounted display (HMD). We also expand on existing methodologies by using dynamic (animated) 3D PC objects in an MR environment.

The platform provides multiple options for configuring the rendering of dynamic PC objects and meshes, including changing the content, quality, viewing distance, and representation, as well as previewing and interacting with the PC objects. Additionally, the proposed platform can be deployed to create subjective tests of the visual quality of dynamic PCs and
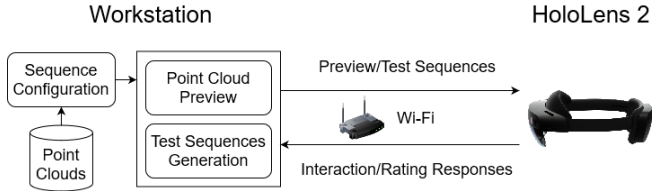
Fig. 1: Platform architecture

meshes in MR environments. The proposed platform has been used for such a subjective study, the results of which are available in [5]. Finally, the platform is made open source and public via GitHub[1].

## II. PROPOSED PLATFORM FOR SUBJECTIVE TESTS IN MIXED REALITY ENVIRONMENTS

The platform is built using Unity[2]. The Mixed Reality Toolkit (MRTK) 2[3] from Microsoft is utilized to work with the HoloLens 2.

Despite the HoloLens 2 having standalone capabilities, we use Holographic Remoting[4] from MRTK 2 to run the platform on a workstation while taking input from and sending output to the HoloLens 2. The architecture is shown in Fig 1. A workstation with an Intel Core i9-13900K processor, 64 GB of DDR5-4800 MHz memory and an NVIDIA RTX 4070 Ti GPU is utilized to run the system.

The platform has two major functionalities: *(i)* point cloud previewing and *(ii)* subjective testing. The preview function allows the tool user (*e.g.*, researchers, content providers, subjective test directors) to spawn and configure PC objects to study and compare the various configurations. Observations from the previews can then be utilized to set up subjective tests using this platform.

### A. Point Cloud Previews

The purpose of the preview functionality is to allow the tool users to explore and compare various configurations of the point clouds. These configurations are controlled via a menu in the HoloLens 2 device. Multiple objects can be added and viewed side by side, and each object can be configured individually. As shown in Fig. 2, an object can be configured in the following properties.

*1) Point Cloud:* The PC objects to be presented are based on the files placed in the project repository. We use the PCs from the 8i Voxelized Full Bodies Database [3], scaling them appropriately to be life-sized. The platform allows the tool users to choose between these PCs for each object displayed, allowing the user to compare configurations for the same or multiple PCs simultaneously.

[1]https://github.com/shivivats-aau/MR-Subjective-Testing-Platform. Accessed: 22 May 2023.
[2]Version 2021.3.19f1. https://unity.com/. Accessed: 20 April 2023.
[3]https://github.com/microsoft/MixedRealityToolkit-Unity. Accessed: 20 April 2023.
[4]https://learn.microsoft.com/en-us/windows/mixed-reality/develop/ native/holographic-remoting-overview. Accessed: 20 April 2023.
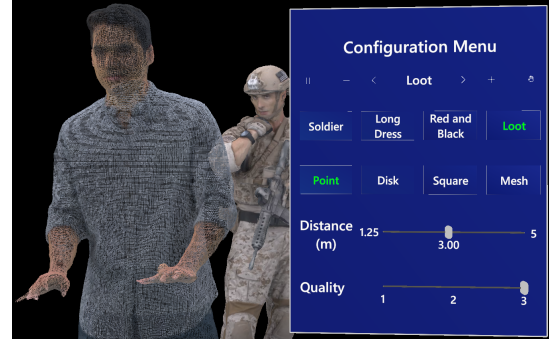
Fig. 2: Configuration control panel and PC objects. The *Loot* object (front) is rendered using the *Point* representation at 3 m from the viewer with quality level 3. The *Soldier* object (at the back) is rendered using the *Square* representation at 5 m distance with the same quality.
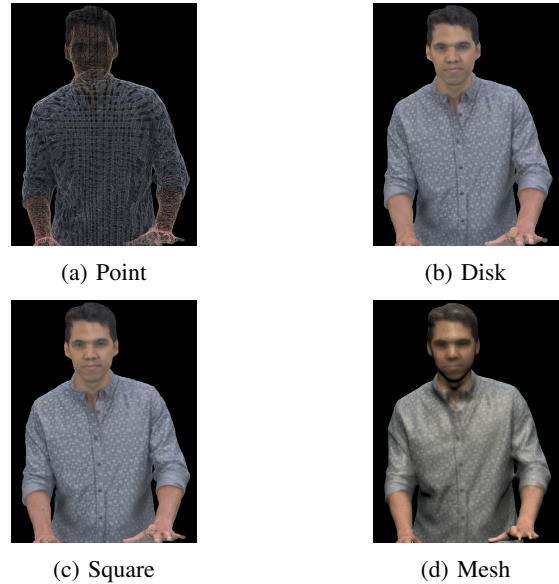


(a) Point

(b) Disk

(c) Square

(d) Mesh

Fig. 3: Representations illustrated by the *Loot* object [3] at 2.5 m distance from the viewer

*2) Representation:* In the demo, the points of the PCs can be rendered in three different ways: points, disks [6], and squares [2]. Furthermore, the PCs can be displayed as meshes. The various configurations are shown in Fig. 3. The conversion from PC to mesh is not part of the platform's features and must be done offline, and the meshes must be stored alongside the PCs in the project. In our case, MeshLab[5] is used to generate filter scripts, which are used with the PyMeshLab library to convert the point clouds into meshes.

*3) Distance:* The distance is controlled via a slider, and the user can position the objects between 1.25 m and 5 m away from them. This distance range was chosen according to the Windows Mixed Reality documentation for "Hologram render distances"[6], which recommends that holograms be placed in this range for best user comfort. However, the tool users can change this range if they so desire.

[5]https://www.meshlab.net/. Accessed: 29 April 2023.
[6]https://learn.microsoft.com/en-us/windows/mixed-reality/develop/ advanced-concepts/hologram-stability. Accessed: 20 April 2023.

*4) Quality:* The quality of the objects can be adjusted based on the representations stored in the project repository. Any encoding into various qualities must be done offline. We use three presets from the MPEG PCC reference software Test Model Category 2 [4] to encode the PCs into three quality levels that we label 1, 2, and 3, going from the lowest to the highest quality. In the case of meshes, we considered three tree depths 6, 7 and 8 for the surface reconstruction, again resulting in three quality levels.

*5) Animation and Interaction:* The sequences are played back at 30 fps, and are thus 10 seconds long in our case. For previewing, each object's animation can also be paused and resumed. Finally, we allow the user to interact manually with the objects to pick them up and place them in custom locations.

### B. Subjective Testing

The second major functionality of this platform is the ability to compose and perform subjective tests within the given parameter ranges. These are single-stimulus tests designed with the purpose of testing the impact of various factors, such as distance and quality, on the perceived quality of the object and, thus, the Quality of Experience (QoE) of the test participant.

These tests can be configured using the Unity user interface (UI) and are divided into "tasks". Within a task, the tool user (researcher or test director) can select a number of configurations for the PCs, similar to the configuration options in the preview. All the possible permutations from the chosen configurations are determined and displayed to the test participant in random order. Randomization removes any bias the participants might obtain by watching the sequences in a particular order.

The Unity UI for the subjective test configuration is shown in Fig. 4. An item of note here is that the quality is always entered in pairs. If different qualities are entered, the sequence switches from the first to the second quality halfway through the playback.

The test workflow is designed so that the participant is asked to rate the perceptual quality of each sequence after watching it. This is made possible via an immersive slider which allows the participants to rate the quality from 1 through 10 with textual guidelines to support the ratings (*i.e.*, 1, 2 – very bad, 3, 4 – bad, 5, 6 – fair, 7, 8 – good, 9, 10 – very good). These ratings are stored in a CSV file with a unique numerical ID assigned to the test participant and a string describing the sequence they just watched. The timestamp of this action is also stored and can be used to synchronize with a separate questionnaire that the participants might fill in, among other usages.

Furthermore, while the test participants perform the test using the HMD, the tests can be monitored by simply looking at the Unity application on a computer screen. This includes tracking the participant's progress and any difficulties they might have during the test.
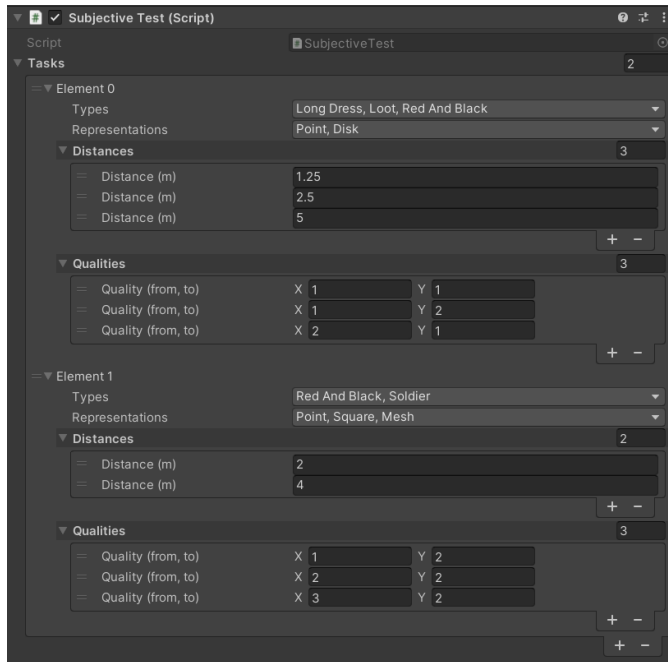


Fig. 4: Subjective test configuration UI

### III. The Demonstrator

First, the presenter, or an individual from the audience, will use the PC preview functionality via the HoloLens 2. The workflow and the various configurations will be shown to the audience using a screen attached to the workstation running the platform.

The second part of the demo will include a brief overview of the subjective test system, showing how to configure a subjective test. The configured test will then be run briefly, illustrating the rating slider and the storage of participant feedback on the disk.

Thus, the audience of the conference can experience the platform's workflow as well as experience and interact with the point clouds in points, square, disk, or mesh representations.

### IV. Conclusions and Future Work

We have presented a platform for subjective testing of dynamic point clouds in MR environments using the HoloLens 2. The tool users can preview point cloud (PC) video sequences and configure subjective tests with desired PC properties. Test participants' feedback can be obtained and recorded for every PC sequence watched.

Future work on this platform includes supporting double-stimulus tests and introducing stall events (rebuffering) of configurable duration in the test sequences. The platform can also be expanded to include other devices supported by MRTK 2.

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