

A Comparative Evaluation of 3D Gaussian Splatting and LiDAR for Digitizing Handheld Objects in VR

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Abstract— This paper compares the effectiveness of mobile device-based LiDAR and 3D Gaussian Splatting for digitizing small objects for interactable use in immersive VR applications. The study aims to determine the most accurate and efficient consumer-accessible method for translating handheld real-world objects into immersive virtual environments using mobile phones with LiDAR sensors. Using a Meta Quest 2 controller as the test object—chosen for its complex geometry with a torus-like ring and a genus of 1, a combination of curved and flat surfaces, and interactable buttons—we conducted multiple mesh and 3D Gaussian Splatting (3D-GS) scans using two mobile apps: SiteScape for LiDAR-based point clouds, and Scaniverse for both mesh and Splat-based scans. The dimensional accuracy of each scanning technique was evaluated by comparing cloud-to-mesh distance of the generated models in the CloudCompare software against a highly accurate reference controller model from Meta, averaging the results of three models for each method to account for environmental variability. The models are then imported into Unreal Engine for a VR application to assess the controller’s visual quality and interaction fidelity. The findings of this study provide a comparative analysis of the strengths and weaknesses of each method, offering insights into the most optimal mobile 3D scanning techniques for users to digitize small objects for interactive and immersive VR applications.

Keywords— 3D gaussian splatting, VR object digitization, LiDAR-based 3D scanning, multimodal capturing and reconstruction, user experience and usability

I. INTRODUCTION

The growing accessibility of immersive virtual reality (VR) technologies, driven by the wider availability of consumer-grade VR headsets [1], has sparked wider interest in immersive virtual experiences and high-fidelity virtual simulations across diverse domains, calling for innovations in virtual content creation. For applications such as serious games, design and manufacturing applications or VR simulations, the accurate digitization of physical objects presents a critical challenge, as accurate representations of these objects are essential for maintaining realism and higher interaction fidelity.

As conventional digital content creation workflows in game engines are primarily shaped and optimized for the video game industry, the processes may not always accommodate the speed and accuracy required by other industrial applications. Traditional methods of digitizing a real object mostly rely on a

low-fidelity recreation of the object by 3D artists and texture artists with reference images and drawings or 3D scanning technologies that often require expensive equipment and are not readily accessible to the average consumer. The need for quick and accessible approaches to object digitization in VR remains crucial.

However, the advent of mobile devices equipped with LiDAR (Light Detection and Ranging) sensors and democratized access to 3D scanning technologies as a powerful and more precise alternative to photogrammetry. Notably, the LiDAR scanner available in Apple’s Pro line of mobile products since iPhone 12 Pro and iPad Pro 2020 [2], [3], made low-cost surveying, mapping, and digitization possible for consumers. In addition, new techniques like 3D Gaussian Splatting (hereafter 3D-GS), which uses splatting to render three-dimensional (3D) scenes, provide users and developers a powerful tool for creating digital replicas of real-life objects and volumes. Enabling everyday users to digitize objects for surveying, gaming, education, and prototyping, the application of these mobile-based technologies for VR development remains promising.

This study aims to evaluate and compare the effectiveness of mobile device-based LiDAR and 3D-GS for digitizing objects for use in immersive VR. Specifically, the paper focuses on identifying which consumer-accessible method offers the most accurate and efficient way to create digital representations of small and handheld objects for interaction in VR. To achieve this, we selected the Meta Quest 2 controller as the test object due to its familiar use in VR applications and its complex geometry that includes a torus-like ring, a combination of curved and flat surfaces, and interactable buttons. These features make it an ideal candidate for evaluating the capabilities of both 3D scanning methods.

We used an iPhone 15 Pro to conduct multiple scans using two mobile applications that are commercially available in the App Store: SiteScape for LiDAR-based scanning and Scaniverse for both LiDAR-based and 3D-GS-based scans, exporting the results as point clouds provided by the respective apps for each method. Three scans were performed, and outcomes were averaged to account for environmental variability and increased reliability of the results. Each scanning technique’s geometric and dimensional accuracy was compared via the CloudCompare software to calculate cloud-to-mesh

distances of generated point clouds against a highly accurate reference model mesh provided by Meta, calculating metrics such as Root Mean Square and model coverage. The point clouds were also used to generate mesh models in Rhino 8, which were imported to Unreal Engine to assess their visual quality and interaction fidelity within a VR application.

Through the comparative analysis of this study, we aim to provide insights into the strengths and weaknesses of mobile device-based LiDAR and 3D-GS technologies, informing VR developers and users about the optimal techniques for digitizing small objects for their VR applications, promoting the content creation initiatives by everyday users using accessible technologies.

II. RELATED WORK

3D scanning, which is the process of creating 3D digital representations of physical objects by capturing their geometric and surface features with specialized equipment, has been widely adopted in fields such as architecture, engineering, manufacturing, medical studies, education, cultural heritage preservation, entertainment, and video game development. Among the main methods used for 3D scanning are photogrammetry, LiDAR, and 3D-GS.

LiDAR (Light Detection and Ranging) is a remote sensing technology that emits laser pulses and measures their return time to calculate precise distances. This accurate depth information is processed to create detailed spatial representations as point clouds. Initially prominent in specialized applications such as topographic mapping, archaeology, architecture, and autonomous navigation, LiDAR technologies have significantly advanced with higher resolution outputs and reduced device costs. This evolution enabled its integration into consumer-grade devices, such as gaming console peripherals, robot vacuum cleaners, and smartphones.

While LiDAR technology is able to capture intricate details on objects, previous research has shown that mobile device-based LiDAR struggles with small features, resulting in higher deviations than industrial LiDAR solutions [4]. Furthermore, mobile LiDAR sensors can generate point clouds with a lower resolution and point cloud density than professional-grade equipment, which can impact the accuracy of smaller objects. Therefore, while providing a faster and cost-effective solution for medium-scale volumes, such as room-scale environments and architectural elements [5], [6], [7], it can be insufficient for smaller objects where fine details are crucial.

3D-GS is a novel technique for volume rendering and 3D scene representation, differing from traditional mesh-based and voxel-based approaches. Unlike conventional methods, which rely on explicit 3D mesh creation or dense volumetric representations, 3D-GS uses Gaussians to represent objects in a volumetric point cloud, allowing efficient interpolation and rendering without the need for complex surface geometry [8]. The splatting technique works by projecting Gaussians from 3D space onto 2D image planes for real-time rendering, thus enabling high-quality representations with a compact dataset [9]. This rendering technique has significant reflections on object scanning as well. While traditional object scanning relied on methods like photogrammetry and LiDAR, which capture dense

point clouds to generate surface geometries as meshes, 3D-GS directly represents scanned objects as a collection of Gaussians in a volumetric point cloud. Each Gaussian “blob” holds properties such as position, size, and color. During rendering, these volumetric blobs are splatted onto 2D planes, enabling photorealistic visualization from multiple viewpoints. The result is a highly detailed and smooth representation.

In VR applications, perceptual authenticity and the level of immersion largely depend on the quality of 3D assets used. Precise, high-fidelity models facilitate intuitive and seamless interaction with virtual objects and environments, enhancing presence and engagement. Emerging methodologies make use of 3D scanning to increase immersion and presence. LiDAR and 3D-GS technologies have both been applied to digitizing handheld objects for VR, with varying degrees of success.

Despite these challenges, mobile device-based LiDAR remains a potential solution for rapid and accessible object scanning, with a dimensional accuracy calculated as ± 2 cm in architectural surveying [10] and 5% in room-scale immersive environment creation [11]. A previous study has shown that LiDAR provides greater precision for virtual object positioning in augmented reality (AR) applications compared to photogrammetric methods [12]. Given the trade-offs in detail and accuracy, researchers and developers continue to explore alternative scanning methods to improve the fidelity of 3D models for use in XR applications.

The ability to rapidly create highly realistic models with 3D-GS has made it a preferred method for VR developers and researchers [9], [13], [14].

As shown above, numerous studies have utilized and compared 3D scanning methods and their effectiveness for VR applications. While previous works have evaluated the effectiveness of LiDAR and 3D-GS in various contexts, there is a lack of direct comparison between these technologies when applied to small, handheld objects for VR applications. This study aims to fill that gap by providing a comparative evaluation of both methods using mobile-based LiDAR and 3D-GS to a digitize small object with intricate geometry, using the Meta Quest 2 controller test as a case study.

III. METHODOLOGY

This section details the selection of the test object, the apparatus used, the scanning procedures using mobile apps, the dimensional accuracy comparison using CloudCompare software, and the qualitative assessment of the visual quality and interactive experience of the scanned objects in a VR application.

A. Test Object: Meta Quest 2 Controller

To present a comparative evaluation of the geometric and dimensional accuracy, visual quality, and interaction fidelity of 3D scans of handheld objects created with LiDAR and 3D-GS, scans were conducted on a Meta Quest 2 controller, also known as the Touch controller. Similar to the use of the Utah teapot in 1975 [15] with its smooth curved surfaces and handle making it an optimal object for demonstrating the capabilities of 3D computer graphics, the Quest 2 controller was chosen as a test object in this study for several reasons:

(1) *Topological complexity*: The controller features a torus-like ring, resulting in a topology with a genus of 1. The inner and outer surfaces of the ring and the occlusion and shadow it casts on the top panel introduces challenges in capturing the object’s shape.

(2) *Geometrical variety*: The controller’s body combines curved and flat surfaces, offering a diverse range of geometrical features to test the versatility of scanning methods.

(3) *Fine details*: The total height of the controller is 13 cm, with a diameter of 9 cm on the ring. Interactable elements such as convex and concave buttons and the thumbstick provide challenging and intricate details.

(4) *Relevance in VR applications*: As one of the standard input devices in VR, familiarity and ecological validity of the object are higher for VR users.



Fig. 1. Meta Quest 2 right controller – The digital reference model (left), the physical controller used in the scans (center), and the scanning setup (right).

The reference model for the controller was downloaded from Meta’s official developers’ website, providing left and right controllers in FBX format in three levels of detail [16]. Only the right controller model, consisting of 26,635 vertices and 47,512 triangles, was utilized for this study. With its high level of precision and detail, this model was treated as the ground truth for all accuracy comparisons. Figure 1 shows the digital reference model, the physical controller used in the scans, and the scanning setup with the controller mounted on a stand.

B. Apparatus and Setup

All scans were conducted using an iPhone 15 Pro, using its built-in LiDAR scanner, specifically the Sony IMX591 LiDAR Single Photon Avalanche Diode (SPAD) sensor [17], along the phone’s processing capabilities. After reviewing commercially available 3D scanning *mobile applications* (hereafter referred to as “apps”) that have LiDAR and 3D-GS capabilities and run on iOS, SiteScape (v1.7.16) and Scaniverse (v4.0.1) were selected due to their similar workflows and promising pilot scan results.

SiteScape, acquired by FARO in 2022, was chosen as it focuses on generating 3D point clouds, in contrast to other apps that focus on generating meshes from the captured point clouds, and has a setting to adjust point density parameter [10]. Scaniverse, acquired by Niantic in 2021, was chosen because of its mesh scanning feature, having the option to export the captured point clouds as high-density color point clouds in PLY format, and the app’s recent support of 3D-GS since March 2024 [18].

The Quest 2 controller was mounted on a black stand and placed on a matte and non-reflective surface to minimize glare

and reflections. Controlled lighting conditions were established to reduce shadows and ensure consistent illumination.

The scans were conducted with three different configurations: (1) LiDAR scanning with SiteScape in the high point density setting, (2) LiDAR scanning with Scaniverse in the mesh mode, and (3) 3D-GS scanning with Scaniverse in the splat mode. For each app and method, three separate scans of the Quest 2 controller were conducted to ensure consistency and minimize the impact of environmental factors.

The scanning process was identical in all nine scans conducted for the scan: A slow and steady circular movement around the controller was performed, maintaining a distance of approximately 0.5 meters to stay within the optimal range of the LiDAR sensor. The scanning covered all angles, including top-down and side views, to capture the complete geometry. Real-time feedback from the app indicated areas needing additional coverage. Each scan took approximately two minutes to complete, as much longer scans resulted in diminished quality due to overlaps for both LiDAR and 3D-GS methods.

Upon the completion of scans, all data were named based on the app and method used, and scan time. The resulting models were exported in PLY format to ensure compatibility with the CloudCompare analysis software. It is important to note that while 3D-GS does not originally generate traditional point clouds, it creates splat-based representations consisting of fuzzy, volumetric elements that blend together to depict the object’s surfaces. However, Scaniverse processes these splat-based models locally on the device, going through steps such as “aligning the captured frames, computing depth, and training splat.” Although the specific methods behind the app’s processing remain undisclosed, they result in a more dense point cloud than LiDAR exports in the end.

C. Dimensional Accuracy Evaluation

The dimensional accuracy of the scans was assessed by comparing the resulting point clouds with the high-fidelity reference model using CloudCompare software. Initially, each of the nine point clouds and the reference model were manually aligned, using the base desk’s corners and the stand as reference points. Then, the Iterative Closest Point (ICP) algorithm was applied to refine the alignment. Finally, the stand, desk, and any other environmental points were removed using the Segment tool, leaving only the controller models for analysis.

The Cloud-to-Mesh Distance tool in CloudCompare was used to compute the distance from each point in the scanned point cloud to the nearest point on the reference mesh model. A signed distance scalar field was generated for each model to visualize areas of significant deviation.

Evaluation metrics extracted for the analysis include the total number of points in the point cloud, point coverage compared to the 26,635 vertices on the reference model, average distance showing the mean of all point-to-surface distances, standard deviation of the distance data, and the maximum distance observed. Additionally, distance field histograms were normalized using equal bin sizes of 5 mm to consistently compare model deviations from the reference. Finally, the Root Mean Square (RMS) metric was calculated for each scan, as it gives more weight to larger errors by taking the square root of

the average of the squared distances between corresponding points. A lower RMS value indicates lower error and higher accuracy of the scanned model relative to the reference.

D. VR Implementation

To evaluate the practical usability of scanned models in VR applications, the point clouds were converted to mesh models. The ShrinkWrap command in Rhino 8 was used to generate a tight-fitting mesh around the point cloud conforming to their geometry. These mesh models were then exported in FBX format to be compatible with Unreal Engine.

Due to the relatively low point cloud density, which did not provide enough resolution for detailed textures, texture mapping was not applied in this study. Proper texture mapping would require either baking textures from the reference model or another photogrammetry model. This would have deviated from the project's primary objective of presenting a quick and accessible method for users to digitize real-life objects without relying on conventional 3D content creation procedures. Therefore, the models were assessed only based on their geometric accuracy and performance within the VR environment.

A VR project was created in Unreal Engine, where the imported models were scripted as pickable scene actors. The right hand input's relative rotation was replicated locally on all imported controllers, allowing users to manipulate all the models simultaneously, even without picking them up. The models were then examined for visual fidelity in immersive VR by the researchers, checking for surface qualities, accurate representation of details, and absence of artifacts, providing feedback on the experience.

IV. RESULTS

The comparative analysis of mobile device-based LiDAR and 3D-GS scans of Quest 2 controllers are organized to address the primary objectives of this study: assessing the dimensional accuracy, model completeness and level of detail, and the model's visual and interactive performance in VR.

The results are based on nine total scans, divided into three groups based on the app and method used: three for Scaniverse 3D-GS, three for Scaniverse LiDAR, and three for SiteScape LiDAR. The values in Table 1 represent the averages across these groups to account for variability in environmental conditions and scanning methods.

Figure 2 visually compares the point clouds generated by different methods and applications. The color bar on the right side of each scan represents the Cloud-to-Mesh Distance (signed distances), with blue to green indicating smaller deviations from the reference model and yellow to red indicating larger deviations. However, it's important to note that since points with negative signed distances (in the blue range) represent areas where the scanned points are located below the surface of the reference model, the placement of 0 on the color scale is critical when interpreting these deviations.

The Reference Model (top left) serves as the highly accurate baseline against which the accuracy of the scans is compared. The Scaniverse 3D-GS (3D Gaussian Splatting) results (top row) show denser, more complete reconstructions of the

controller, with fewer extreme deviations, indicated by the green and yellow regions on the scale representing smaller errors. The Scaniverse LiDAR results (middle row) demonstrate lower point density and more significant errors, particularly in Scan 03, where red and orange points represent areas with large deviations. The SiteScape LiDAR results (bottom row) show the least complete scans, with very sparse point clouds but fewer maximum errors, indicated by red regions.

Table 1 shows that 3D-GS produces more accurate models, with the lowest mean distance of 2.07 mm and RMS error of 3.00 mm, indicating better dimensional accuracy than LiDAR scanning results. Additionally, 3D-GS achieved the highest total number of points on average (17,568), resulting in the highest points coverage of 66%, indicating a higher level of detail and higher similarity to the reference model.

TABLE I. SUMMARY OF MEAN EVALUATION METRICS FOR 3D-GS AND LiDAR-BASED SCANS

Method	Total Points	Points Coverage	Mean Dist. (mm)	σ (mm)	Max. Distance (mm)	RMS (mm)
3D-GS, Scaniverse	17,568	66%	2.07	2.18	14.15	3.00
LiDAR, Scaniverse	12,509	47%	4.56	3.59	35.01	6.24
LiDAR, SiteScape	1,516	6%	5.49	5.13	26.62	7.52

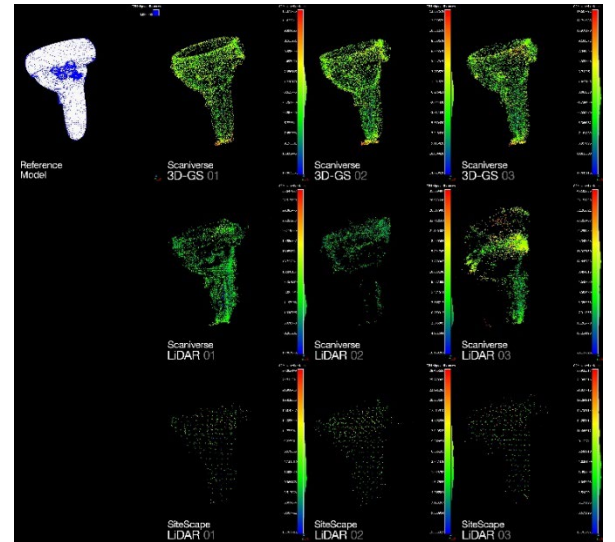


Fig. 2. Comparison of the Cloud-to-Mesh signed distance scalar fields in nine point clouds, compared to the reference model (top left).

In contrast, LiDAR scans have higher mean distances of 4.56 and 5.49 mm and RMS errors of 6.24 mm and 7.52 mm, suggesting at least twice as many deviations from the reference model. Scaniverse LiDAR scans captured 12,509 points with 47% coverage, whereas SiteScape LiDAR scans captured only 1,516 points with a mere 6% coverage of the reference model, indicating a lower detail in addition to the lower accuracy.

The standard deviation (σ) values further highlight the increased variability in LiDAR scans (3.59 mm and 5.13 mm)

compared to 3D-GS scans (2.18 mm). This indicates that LiDAR scans not only have higher RMS errors but also greater inconsistency in the accuracy of the scanned points across different takes.

It is also worth examining the maximum distances, even though they may represent outlier values. The 3D-GS scans have a maximum distance of 14.15 mm on average. Considering the 130 mm size of the Quest 2 controller, this corresponds to an 11% error rate, which is not ideal but is still relatively lower compared to the LiDAR methods. In comparison, Scaniverse LiDAR's maximum distance of 35.01 mm translates to a 27% error rate and SiteScape LiDAR's 26.62 mm results in a 20% error rate. Such high error rates in the LiDAR scans, particularly those exceeding 20%, raise concerns about their suitability for accurately digitizing small interactive objects.

Figure 3 illustrates the percentage distribution of points across different distance ranges (in millimeters) for the three scanning methods.

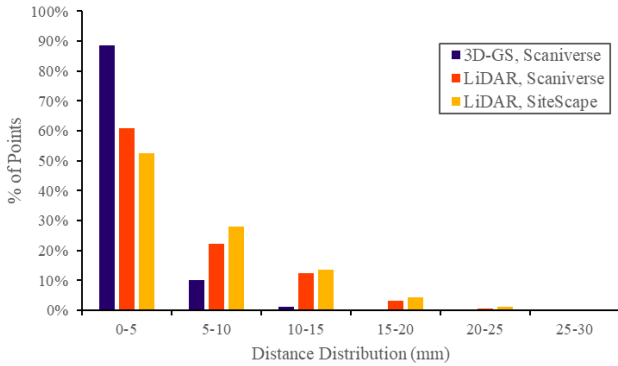


Fig. 3. Percentage distribution of points within specific distance ranges.

Table 1 shows that 3D-GS produces more accurate models, with the lowest mean distance of 2.07 mm and RMS error of 3.00 mm, indicating better dimensional accuracy than LiDAR scanning results. Additionally, 3D-GS achieved the highest total number of points on average (17,568), resulting in the highest point coverage of 66%, indicating a higher level of detail and higher similarity to the reference model.

The 3D-GS scanning method exhibits a dominant concentration of points within the 0-5 mm range (89%), underscoring its superior accuracy in capturing the controller's geometry reinforcing the earlier findings of lower RMS and standard deviation. LiDAR methods' highly accurate range is significantly lower in comparison, with Scaniverse LiDAR at 61% and SiteScape LiDAR at 53% within the same range, indicating consistently fewer highly accurate points.

As the ability to translate accurate 3D scans of physical objects into virtual environments is crucial for the model's visual and interactive features, the results above directly affect the VR implementation observations below.

Figure 4 shows a screenshot of the models generated from the scans during the VR testing, highlighting the differences in model completeness and accuracy.



Fig. 4. Screenshot showing scanned 3D models in VR application.

In the top row, the SiteScape LiDAR models are incomplete, with noisy geometry and some portions of the controller's geometry missing due to a lower points coverage. The middle row, the results of the Scaniverse 3D-GS method, captures the highest detail in comparison, including the ring, body, and triggers, making it the most accurate and complete representation, though the buttons are still absent. In contrast, the bottom row, showcasing Scaniverse LiDAR scans, reveals highly fragmented models, missing critical parts in the body of the second and overlapped double rings in the third, rendering the models unsuitable for VR interactions.

V. DISCUSSION

The results of this study demonstrate a clear advantage of 3D-GS over LiDAR-based scanning methods in terms of dimensional accuracy, level of detail, and interaction fidelity. On average, the 3D-GS method produced models with the lowest mean distance (2.07 mm) and RMS error (3.00 mm), and the highest point coverage (66%), indicating a higher ability to replicate the reference model. In contrast, both LiDAR-based scanning apps exhibited higher mean distances and RMS errors, indicating larger deviations from the reference. The high error rates raise concerns about the reliability of these scans for applications where precision is critical.

Although LiDAR technology is widely used for scanning larger objects and volumes with a typical dimensional accuracy of ± 2 cm—especially in fields like architecture and surveying—the iPhone 15 Pro's LiDAR scanner and the associated apps struggled to capture the fine details of the smaller object in this study. Across the six LiDAR scans conducted, the average mean distance was approximately 5 mm. This highlights the limitations of mobile LiDAR sensors for small-scale, intricate objects. On the other hand, despite documented limitations in metrological accuracy and game engine compatibility of 3D-GS [19], it outperformed LiDAR in geometric fidelity, which is an interesting and unexpected result.

Despite the limitations of LiDAR for small objects, its operational advantages in larger-scale environments remain undisputed, where high point density and precision are less critical than in small, intricate objects.

In the VR implementation of the scanned models, 3D-GS performed significantly better in terms of visual similarity and interactivity. However, challenges remain, particularly with texture generation and missing details, such as the buttons on the Quest 2 controller. Future workflows and studies may focus on

improving the ability to generate textures and fully capture intricate details, ensuring more complete and accurate models for immersive VR applications.

VI. CONCLUSION AND FUTURE WORK

This study has demonstrated that 3D Gaussian Splatting (3D-GS), when used with mobile devices, is the more effective method for digitizing small objects for VR applications, offering superior dimensional accuracy (RMS = 3.00 mm) and better detail compared to LiDAR-based scanning methods. While LiDAR remains useful for scanning larger environments or simpler objects, 3D-GS provides a more reliable solution for creating high-fidelity, interactive objects for immersive VR environments. These findings can help VR developers make informed choices about the most suitable scanning methods as mobile technology continues to advance.

For developers focused on creating assets for immersive virtual environments, 3D-GS proves to be a robust and precise option, though further improvements are needed in the workflow, particularly regarding texture generation and capturing intricate details.

A current limitation is the reliance on proprietary black-box workflows of closed-source mobile applications, i.e., SiteScape and Scaniverse, where no low-level algorithm details are publicly available. Future studies could investigate open-source alternatives and develop transparent benchmarking frameworks to improve reproducibility.

Building on the findings of this study, future research should explore several directions, including re-evaluating the performance of newer generations of mobile LiDAR technologies, optimizing the texture and detail capture process in both 3D-GS and LiDAR, and conducting similar studies for medium-sized objects, room-scale volumes, and large-scale exteriors. These efforts will further refine the best practices for utilizing these scanning technologies in VR development.

ACKNOWLEDGEMENTS

This research was supported by Innovate UK through a Knowledge Transfer Partnership project between Stewart Signs Ltd and the University of Southampton, Winchester School of Art (KTP Project ID: 13577). The authors would also like to thank the project partners.

REFERENCES

- [1] R. Epp, D. Lin, and C.-P. Bezemer, "An Empirical Study of Trends of Popular Virtual Reality Games and Their Complaints," *IEEE Trans Games*, vol. 13, no. 3, pp. 275–286, Sep. 2021, doi: 10.1109/TG.2021.3057288.
- [2] F. King, R. Kelly, and C. G. Fletcher, "Evaluation of LiDAR-Derived Snow Depth Estimates From the iPhone 12 Pro," *IEEE Geoscience and Remote Sensing Letters*, vol. 19, pp. 1–5, 2022, doi: 10.1109/LGRS.2022.3166665.
- [3] Apple, "Apple unveils new iPad Pro with LiDAR Scanner and trackpad support in iPadOS." Accessed: Sep. 09, 2024. [Online]. Available: <https://www.apple.com/uk/newsroom/2020/03/apple-unveils-new-ipad-pro-with-lidar-scanner-and-trackpad-support-in-ipados/>
- [4] M. Vogt, A. Rips, and C. Emmelmann, "Comparison of iPad Pro®'s LiDAR and TrueDepth Capabilities with an Industrial 3D Scanning Solution," *Technologies (Basel)*, vol. 9, no. 2, p. 25, Apr. 2021, doi: 10.3390/technologies9020025.
- [5] W. Rutkowski and T. Lipecski, "Use of the iPhone 13 Pro LiDAR Scanner for Inspection and Measurement in the Mineshaft Sinking Process," *Remote Sens (Basel)*, vol. 15, no. 21, Nov. 2023, doi: 10.3390/rs15215089.
- [6] D. Costantino, G. Vozza, M. Pepe, and V. S. Alfio, "Smartphone LiDAR Technologies for Surveying and Reality Modelling in Urban Scenarios: Evaluation Methods, Performance and Challenges," *Applied System Innovation*, vol. 5, no. 4, Aug. 2022, doi: 10.3390/asi5040063.
- [7] M. Abdelmadjid Talbi, H. Amroun, and M. Ammi, "Cost Effective Rebar Inspection using Point Cloud Data," in *International Conference on Human System Interaction, HSI*, IEEE Computer Society, 2024. doi: 10.1109/HSI61632.2024.10613561.
- [8] A. Dalal, D. Hagen, K. G. Robbersmyr, and K. M. Knausgård, "Gaussian Splatting: 3D Reconstruction and Novel View Synthesis: A Review," *IEEE Access*, vol. 12, pp. 96797–96820, 2024, doi: 10.1109/ACCESS.2024.3408318.
- [9] B. Fei, J. Xu, R. Zhang, Q. Zhou, W. Yang, and Y. He, "3D Gaussian Splatting as New Era: A Survey," *IEEE Trans Vis Comput Graph*, pp. 1–20, 2024, doi: 10.1109/TVCG.2024.3397828.
- [10] A. Spreafico, F. Chiabrando, L. Teppati Losè, and F. Giulio Tonolo, "The iPadPro Built-In LIDAR Sensor: 3d Rapid Mapping Tests and Quality," *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, vol. XLIII-B1-2021, no. B1-2021, pp. 63–69, Jun. 2021, doi: 10.5194/isprs-archives-XLIII-B1-2021-63-2021.
- [11] B. A. Lease, D. H. Chiam, K. H. Lim, and J. T. S. Phang, "Development of 3D Scanned Environment in Virtual Reality," in *2023 International Conference on Digital Applications, Transformation & Economy (ICDATE)*, IEEE, Jul. 2023, pp. 1–4, doi: 10.1109/ICDATE58146.2023.10248625.
- [12] [K. Skabek, P. Ozimek, and D. Rola, "Photogrammetric vs. lidar methods for augmented reality," in *ECMS 2024 Proceedings edited by Daniel Grzonka, Natalia Rylko, Grazyna Suchacka, Vladimir Mityushev*, ECMS, Jun. 2024, pp. 513–520. doi: 10.7148/2024-0513.
- [13] H. Song, "Toward Realistic 3D Avatar Generation with Dynamic 3D Gaussian Splatting for AR/VR Communication," in *2024 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)*, IEEE, Mar. 2024, pp. 869–870. doi: 10.1109/VRW62533.2024.00356.
- [14] Y. Jiang *et al.*, "VR-GS: A Physical Dynamics-Aware Interactive Gaussian Splatting System in Virtual Reality," in *Special Interest Group on Computer Graphics and Interactive Techniques Conference Conference Papers '24*, New York, NY, USA: ACM, Jul. 2024, pp. 1–1. doi: 10.1145/3641519.3657448.
- [15] D. C. Brock, "Past forward: world's most famous teapot [Past forward]," *IEEE Spectr*, vol. 54, no. 11, pp. 68–68, Nov. 2017, doi: 10.1109/MSPEC.2017.8093819.
- [16] Meta, "Meta Quest Hardware Art," Meta Developers. Accessed: Sep. 09, 2024. [Online]. Available: https://developers.meta.com/horizon/downloads/package/oculus-controller-art/?locale=en_GB
- [17] TechInsights, "iPhone 15 Pro Max Rear LiDAR Camera Process Flow Analysis," Dec. 2023. Accessed: Sep. 09, 2024. [Online]. Available: <https://library.techinsights.com/reverse-engineering/analysis-view/PFA-2308-801>
- [18] Scaniverse, "Scaniverse introduces support for 3D Gaussian splatting," Scaniverse.com. Accessed: Sep. 01, 2024. [Online]. Available: <https://scaniverse.com/news/scaniverse-introduces-support-for-3d-gaussian-splatting>
- [19] Scaniverse, "How To Use Scaniverse - 3D Scanner + LiDAR + Gaussian Splatting for iOS and Android," Scaniverse.com. Accessed: Sep. 01, 2024. [Online]. Available: <https://scaniverse.com/support>