Leveraging Affordable Solutions for Stereo Video Capture in Virtual Reality Applications

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Abstract: Stereo video is essential for creating immersive virtual reality experiences by providing depth perception and enhancing realism. However, capturing high-quality stereo video often requires expensive professional equipment, such as specialized stereo lenses and high-resolution cameras, which poses significant financial barriers for independent content creators and small studios. This paper explores affordable alternatives for stereo video capture, specifically utilizing the built-in cameras of the Meta Quest 3 MR (mixed reality) headset. We compare the capabilities of the Meta Quest 3 with high-end equipment like the Canon EOS R7 and dual fisheye lenses, whose cost is significantly higher (approximately seven times more). Our analysis includes a comparison of display and camera resolutions of popular VR head-mounted displays, revealing that the current VR headsets' display resolutions do not fully utilize the high capture resolutions offered by professional cameras. We provide detailed instructions for setting up the Meta Quest 3 for stereo video capture and present examples of videos captured in both indoor and outdoor environments. The findings suggest that affordable devices like the Meta Quest 3 are capable of producing stereo video content suitable for the present virtual reality technology landscape. The cost savings and operational efficiencies make it a practical option for content creators. We conclude that, given the display limitations of current VR HMDs, investing in high-end capture devices may not yield significant benefits. As VR technology advances and HMD display resolutions improve, the advantages of professional capture equipment may become more pronounced.

1 INTRODUCTION

The advent of virtual reality (VR) has revolutionized the way users interact with digital content, offering immersive experiences that transcend traditional media boundaries. Central to this immersion is the use of stereo video, which provides depth perception and a more lifelike representation of the virtual environment. Stereo video simulates human binocular vision by presenting two slightly offset images to each eye, creating the illusion of three-dimensionality (Fuchs, 2017).

In recent years, there has been a surge in VR content creation and consumption. High-quality VR experiences are no longer confined to large studios with significant resources; independent creators and small studios are increasingly contributing to the VR ecosystem (Slater and Sanchez-Vives, 2016). However, the tools required to produce high-quality stereo video content often come with prohibitive costs. Professional equipment like the Canon RF 5.2mm f/2.8 L Dual Fisheye Lens, priced at approximately $ 1.700, and the Canon RF-S 7.8mm f/4 STM Dual Lens at around $ 500, represent significant investments (Canon, 2023b; Canon, 2023c). Additionally, the Canon EOS R7 Mirrorless Camera body alone costs about $ 1.300 without any lenses (Canon, 2023a). Such expenses create barriers for content creators who wish to produce professional-grade VR experiences but lack substantial financial resources. The aforementioned high end equipement is illustrated in Figure 1.

As an alternative, affordable solutions have emerged that leverage existing hardware to capture stereo video content effectively. Meta Quest 3[1], a standalone VR headset priced at around $ 500, not only provides a platform for VR consumption but also possesses built-in cameras capable of capturing stereo

[1]https://www.meta.com/fr/en/quest/quest-3

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Figure 1: High end equipment for stereo video capture.

video. By utilizing the headset's own hardware, creators can bypass the need for expensive cameras and lenses, reducing the overall cost of production.

This paper explores the viability of using the Meta Quest 3 as a low-cost solution for stereo video capture in VR applications. We compare the costs and technical capabilities of high-end equipment with more affordable alternatives, examining whether the superior specifications of professional devices are fully utilized given the current display resolutions of popular VR headsets. Our analysis includes a comparison of display and camera resolutions among the most widely used VR headsets to assess if the higher resolution offered by professional cameras translates into perceptible improvements in user experience.

The objectives of this study are twofold:

1. To demonstrate that affordable methods, such as using the Meta Quest 3, are capable of capturing stereo video suitable for immersive VR experiences.
2. To evaluate whether the investment in high-end capture devices is justified, considering the display resolution limitations of current VR head-mounted displays (HMDs).

By addressing these objectives, we aim to provide insights that can inform content creators about cost-effective strategies for VR production and stimulate discussions on the necessity of expensive equipment in the context of current VR technology limitations.

2 STEREO CAPTURE APPROACHES

Stereo content capture for VR applications has been a significant area of research and development, leading to various methods and devices ranging from professional high-end equipment to low-cost custom solutions.

Peleg and Ben-Ezra (Peleg and Ben-Ezra, 1999) pioneered the creation of stereo panoramas using a single rotating camera. Their method captures images at incremental angles and stitches them to form panoramic stereo pairs. This approach demonstrated that stereo content could be generated without specialized stereo cameras, providing a cost-effective solution for immersive content creation.

Anderson et al. (Anderson et al., 2016) introduced Google's Jump system, a professional-grade stereoscopic camera rig composed of 16 synchronized cameras arranged in a circular array. The system enables high-resolution, 360-degree stereo video capture and employs advanced computational photography algorithms to seamlessly stitch the footage. This work significantly contributed to professional VR content production by providing high-quality immersive experiences.

Facebook Engineering (Facebook Engineering, 2016) unveiled the Surround 360 system, an open-source, high-quality 3D-360 video capture solution. Consisting of a 17-camera setup, the system is designed to efficiently capture and render 3D-360 videos. By releasing the hardware designs and stitching code to the public, Facebook encouraged innovation and accessibility in the VR content creation community.

Tremblay et al. (Tremblay et al., 2019) proposed a low-cost 360 stereo photography and video capture system that leverages consumer-grade cameras and 3D-printed mounts. Their approach aims to make immersive VR content creation more accessible by reducing hardware costs while maintaining reasonable quality. The system demonstrates that effective stereo content can be produced with minimal investment, promoting wider adoption of VR technologies.

In addition to these research initiatives, commercial devices have emerged to meet the growing demand for VR content. The Insta360 Pro 2[2] is a professional 360-degree camera capable of capturing high-resolution (up to 8K) stereoscopic video. It features advanced functionalities such as real-time image stabilization, HDR support, and long-range wireless control, making it suitable for professional filmmakers and VR content creators. Priced at approximately $4,500 USD, it offers high-end performance for commercial applications.

Conversely, the Stereolabs ZED 2[3] is a more affordable stereo camera priced around $530 USD. While it does not capture 360-degree content, it provides real-time depth sensing and spatial mapping, which are essential for VR and augmented reality (AR) applications that require environmental understanding. Its lower cost and ease of integration make it accessible to developers and researchers focusing on depth-based VR experiences. Table 1 summarizes

[2]https://www.insta360.com/product/insta360-pro2

[3]https://www.stereolabs.com/en-br/products/zed-2

all the approaches mentioned in this section.

3 DISPLAYS AND CAMERA RESOLUTIONS

To evaluate the necessity of high-resolution capture devices, we compare the display and camera resolutions of the most widely used VR HMDs. The selected HMDs for this comparison are: Meta Quest 3, Valve Index, HTC Vive Pro 2, PlayStation VR2 and Pimax Vision 8K X

These devices represent a range of consumer and prosumer VR headsets available as of 2023 and are illustrated in Figure 2.

Figure 2: Selected VR headsets.

Table 2 summarizes the key specifications of the selected VR HMDs, including display resolution per eye, refresh rate, field of view (FOV), and any built-in camera capabilities.

The display resolutions of current VR HMDs, while significantly improved over earlier generations, still lag behind the high-resolution capabilities of professional cameras like the Canon EOS R7, which features a 32.5-megapixel sensor capable of capturing images at 6960×4640 pixels (Canon, 2023a). In contrast, the highest-resolution VR headset in our selection, the Pimax Vision 8K X, provides a resolution of 3840×2160 pixels per eye (Pimax, 2023).

Moreover, Meta Quest 3, which is both a MR headset and our proposed low-cost stereo video capture device, offers a resolution of 2064×2208 pixels per eye (Meta, 2023). While this is lower than the resolutions offered by professional cameras, it aligns with the display capabilities of current VR HMDs, ensuring that the captured content matches the maximum displayable resolution.

The discrepancy between the high-resolution capture capabilities of professional cameras and the lower display resolutions of VR HMDs raises questions about the practical benefits of using such cameras for VR content. Since VR headsets cannot display the full resolution provided by high-end cameras, the additional detail captured is effectively lost during the content consumption phase.

This mismatch suggests that investing in expensive, high-resolution capture equipment may not yield perceptible improvements in the user experience when viewed on current-generation VR HMDs. As a result, more affordable capture solutions like the Meta Quest 3's built-in cameras may offer sufficient quality for immersive VR experiences without the need for professional-grade equipment.

Table 3 highlights the comparison between camera resolutions and VR HMD display capabilities.

As shown in Table 3, the capture resolutions of professional cameras far exceed the display capabilities of current VR headsets. This reinforces the notion that the benefits of high-resolution capture devices are not fully realized with today's VR display technology. Also, low resolution capture devices may benefit from artificial intelligence methods that can enhance image quality and resolution, such as Real-ESRGAN (Wang et al., 2021).

The analysis suggests that the current limitations of VR HMD display resolutions do not necessitate the use of high-end, high-resolution capture devices for creating immersive VR content. Affordable alternatives, such as the Meta Quest 3, provide adequate resolution that aligns with what users can experience through existing VR hardware.

This finding supports the argument that more cost-effective solutions for stereo video capture are not only sufficient but also practical for contemporary VR applications. As VR technology evolves and display resolutions increase, the need for higher-resolution capture devices may become more pressing. However, at present, affordable options offer a favorable balance between cost and performance.

4 STEREO CAPTURE WITH META QUEST 3

In this section, we provide a guide on how to configure the Meta Quest 3 for stereo video recording. We also present examples of short videos captured in both indoor and outdoor settings.

4.1 Setup Instructions

Meta Quest 3 is equipped with MR capabilities, including high-resolution cameras that can be utilized for stereo video capture. To capture stereo video using Meta Quest 3, one must follow these steps:

1. **Update Firmware and Software:** Ensure that

Table 1: Comparison of Stereo Content Capture Methods and Devices.

Work/Device	Hardware Type	Approach	Advantages	Limitations
(Peleg and Ben-Ezra, 1999)	Single rotating camera	Stereo panorama creation	Cost-effective, simple setup	Time-consuming capture process
(Anderson et al., 2016)	Professional rig	16-camera circular array	High-resolution, seamless stitching	High cost and complexity
(Tremblay et al., 2019)	Consumer cameras	Low-cost 360° stereo capture	Affordable, accessible	Lower image quality
(Facebook Engineering, 2016)	Professional rig	17-camera system	Open-source, high-quality output	Complex setup
Insta360 Pro 2	Commercial device	360° stereoscopic camera	High-resolution, professional features	High price
Stereolabs ZED 2	Commercial device	Stereo camera with depth sensing	Affordable, depth mapping	Not 360°, lower resolution

Table 2: Specifications and Prices of Selected VR Head-Mounted Displays.

HMD	Resolution	Refresh Rate	FOV	Cameras	Price (USD)
Meta Quest 3	2064 × 2208 (per eye)	Up to 120 Hz	110°	4 MP RGB	\$500
Valve Index	1440 × 1600 (per eye)	80–144 Hz	130°	Dual RGB	\$1.000
HTC Vive Pro 2	2448 × 2448 (per eye)	90 or 120 Hz	120°	Dual RGB	\$800 (headset only)
PlayStation VR2	2000 × 2040 (per eye)	90 or 120 Hz	110°	4 Cameras	\$550
Pimax Vision 8K X	3840 × 2160 (per eye)	75, 90 Hz	200°	None	\$1.300

the Meta Quest 3 headset is updated to the latest firmware version. Check for updates in the device settings.

2. **Enable Developer Mode:** To access advanced features, you need to enable Developer Mode:
   - Install the Meta Quest app (Meta Horizon) on your smartphone and pair it with the headset.
   - In the app, navigate to *Menu* → *Devices* → *Developer Mode* and toggle it on.
3. **Configure Capture Settings:** Set the desired resolution and frame rate for your recording. Meta Quest 3 supports up to 4K resolution at 30 fps for MR capture.
4. **Install SideQuest:** Download and install SideQuest on your computer from the official website. Connect Meta Quest 3 to the PC via a USB-C cable and allow USB debugging on the headset.
5. **Execute Custom Commands:** In SideQuest, access the "Custom Commands" section and enter the required commands to enable 3D recording.
6. **Record Videos:** Use the standard recording function on the headset to capture 3D content. This recording will capture the stereo view needed for videos with depth.
7. **Transfer and View:** Transfer the recorded videos to your computer or through the Meta Horizon app. Use a video player compatible with 3D content to view the videos in stereo.
8. **Edit and Share:** Edit the videos, if necessary, to enhance the viewing experience, and share them on platforms that support 3D content, allowing others to experience the depth effect of the videos captured on the Meta Quest 3.

To achieve the best possible video quality, consider the following tips:

1. **Lighting Conditions:** Good lighting is crucial for high-quality video capture. Ensure that the environment is well-lit to minimize noise and enhance image clarity (Jackman, 2020).
   (a) *Indoor Settings:* Use artificial lighting to illuminate the area evenly. Avoid harsh shadows by using diffused light sources.
   (b) *Outdoor Settings:* Capture videos during daylight hours. Overcast days provide soft, even lighting, while direct sunlight can create high contrast and shadows.
2. **Stabilization and Movement**: Smooth camera movement enhances the viewing experience in VR. Meta Quest 3's built-in stabilization helps reduce shakiness.
   (a) *Handheld Capture:* Hold the headset steadily or use a mount to minimize motion blur.
   (b) *Dynamic Scenes:* When capturing moving subjects, maintain a consistent speed and avoid abrupt movements.

4.2 Examples of Captured Videos

To evaluate the stereo video capture capabilities of Meta Quest 3, we recorded one indoor and one outdoor scene:

1. **Indoor Example**: An indoor scene was recorded in a living room setting, featuring static objects and moderate ambient lighting, as illustrated in Figure 3.
   (a) **Setup:** The room was illuminated with overhead LED lights providing even lighting.
   (b) **Result:** The captured video displayed good depth perception and color accuracy. Details of objects were clear, and minimal noise was observed.

Table 3: Comparison of Camera Resolutions and VR HMD Display Resolutions.

Device	Capture Resolution	Display Resolution (per eye)
Canon EOS R7	6960×4640	N/A
Meta Quest 3 Cameras	Approx. 1280×720	2064×2208
HTC Vive Pro 2	N/A	2448×2448
Valve Index Cameras	960×960	1440×1600
Pimax Vision 8K X	N/A	3840×2160

2. **Outdoor Example**: An outdoor scene was captured in a park during the afternoon, as illustrated in Figure 4.
   (a) **Setup:** Natural daylight provided ample lighting. The scene included moving subjects such as people walking and trees swaying.
   (b) **Result:** The video showcased vibrant colors and effective depth cues. Motion was smooth, and the stereo effect enhanced the realism of the scene.

Figure 3: Indoor stereo scene captured with Meta Quest 3. (Available at link).

Figure 4: Outdoor stereo scene captured with Meta Quest 3. (Available at link).

5 DISCUSSION

In this section, we analyze the results of our exploration of using Meta Quest 3 for stereo video capture in VR applications. We assess the quality and depth perception achieved (subsection 5.1), compare the performance of the Meta Quest 3 with professional equipment (subsection 5.2), evaluate the cost-benefit implications (subsection 5.3), discuss the impact on content creation (subsection 5.4), and acknowledge the limitations and potential areas for future improvement (subsection 5.5).

5.1 Quality and Depth Perception Analysis

The stereo videos captured using the Meta Quest 3 demonstrated satisfactory quality for VR applications. The depth perception was effective, providing an immersive experience when viewed through the headset.

- **Resolution:** While the capture resolution is lower than that of professional cameras, it aligns with the headset's display capabilities, resulting in a coherent viewing experience.
- **Depth Accuracy:** The stereo separation provided accurate depth cues, essential for immersion in VR environments (Cutting and Vishton, 1995).
- **Limitations:** Some limitations were noted in low-light conditions, where increased noise affected image clarity. Additionally, rapid movements could introduce motion blur.

5.2 Performance Evaluation

The stereo videos captured using Meta Quest 3 demonstrate that affordable VR headsets can serve as viable tools for content creation. While professional equipment like the Canon EOS R7 paired with dual fisheye lenses offers higher capture resolutions and greater control over imaging parameters, Meta Quest 3 provides sufficient quality for the resolutions supported by current VR HMDs.

Professional cameras offer higher resolution footage, resulting in sharper images with finer details. However, the difference is less perceptible when the content is viewed on VR headsets with lower display resolutions (Wang et al., 2022).

5.3 Cost-Benefit Analysis

The financial implications of using the Meta Quest 3 for stereo video capture are significant. The combined cost of professional equipment (camera body and lenses) can exceed $3,000, whereas the Meta Quest 3 costs approximately $500 and serves both as a capture device and a VR headset.

- **Initial Investment:** The lower upfront cost makes the Meta Quest 3 an attractive option for independent creators and small studios with limited budgets.
- **Operational Efficiency:** Using a single device for both content creation and consumption streamlines the workflow and reduces the need for additional equipment.
- **Return on Investment (ROI):** The reduced cost lowers the financial risk associated with VR content production, potentially leading to a higher ROI for creators.

While professional equipment offers superior technical capabilities, the marginal benefits may not justify the substantial additional cost, especially when considering the display limitations of current VR HMDs.

5.4 Impact on Content Creation

The accessibility of affordable capture methods like Meta Quest 3 has the potential to democratize VR content creation.

- **Lowering Barriers to Entry:** Reduced costs enable a broader range of individuals and organizations to produce VR content, fostering diversity and innovation in the VR ecosystem (Ververidis et al., 2022).
- **Educational Applications:** Educational institutions and students can leverage affordable devices for learning and experimentation without significant financial constraints (Freina and Ott, 2015).
- **Community Development:** An increase in content creators can lead to a more vibrant community, encouraging collaboration and the sharing of best practices.

By making VR content creation more accessible, affordable capture methods contribute to the growth and sustainability of the VR industry.

5.5 Implications for High-End Equipment

Our findings suggest that while high-end capture devices offer superior technical specifications, their advantages are not fully realized given the current display limitations of VR HMDs. As VR headset resolutions increase, the benefits of professional equipment may become more pronounced (Renganayagalu et al., 2021).

Content creators should consider their target audience and the platforms on which their content will be consumed when deciding on the appropriate level of investment in capture equipment. For many applications, especially those aimed at widespread accessibility, affordable solutions like the Meta Quest 3 provide a practical balance between quality and cost.

6 CONCLUSION

In this paper, we have explored the viability of using affordable devices, specifically Meta Quest 3, for capturing stereo video suitable for virtual reality applications. Our investigation addressed two primary objectives: demonstrating the capabilities of the Meta Quest 3 in stereo video capture and evaluating whether investing in high-end capture devices is justified given the current display limitations of VR HMDs.

Our findings indicate that Meta Quest 3 serves as a practical and cost-effective solution for stereo video capture. The device's built-in cameras can produce immersive stereo content that aligns with the display resolutions of current VR HMDs. Through comparative analysis, we observed that while professional equipment like the Canon EOS R7 with specialized lenses offers superior technical specifications, the advantages are not fully realized when the content is consumed on VR headsets with lower display resolutions.

The analysis of VR HMDs revealed that even the most advanced consumer headsets have display resolutions that do not match the high capture resolutions of professional cameras. For instance, the Pimax Vision 8K X, one of the highest-resolution headsets available, offers 3840×2160 pixels per eye (Pimax, 2023), which is still lower than the resolutions captured by professional-grade cameras. This mismatch suggests that the additional detail captured by expensive equipment does not significantly enhance the user experience in the current VR landscape.

Moreover, the cost-benefit analysis underscores the practicality of using affordable devices like the Meta Quest 3. The substantial cost savings make VR content creation more accessible to independent creators, educational institutions, and small studios. This democratization of VR content production can lead to a more diverse and vibrant VR ecosystem.

However, for high-end capture devices to make sense and fully utilize their capabilities, advancements in VR HMD technology are necessary. Specifically, significant increases in display resolutions are required to display the high-quality images captured by professional cameras and lenses effectively. As VR technology evolves and HMD resolutions improve, the benefits of using high-resolution capture devices will become more apparent.

Looking ahead, the VR industry is poised for continued growth and technological advancement. As display technologies improve, with higher resolutions and wider fields of view, the demand for higher-quality content will increase (Renganayagalu et al., 2021). In this context, professional capture equipment will play a more critical role in delivering the visual fidelity that next-generation VR experiences will demand.

Content creators should remain adaptable, balancing the need for quality with practical considerations of cost and technology limitations. In the interim, leveraging affordable solutions like the Meta Quest 3 allows creators to produce engaging content without prohibitive investment, fostering innovation and experimentation within the VR community.

Our study reinforces the notion that affordable options for stereo video capture are not only viable but also well-suited to the current state of VR technology. While high-end devices offer superior capabilities, their advantages are constrained by the limitations of present-day VR HMDs. As technology progresses, the synergy between capture devices and display hardware will become increasingly important. Until then, devices like Meta Quest 3 provide a practical and accessible means for creators to contribute to the evolving world of virtual reality.

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