Experimental Immersive 3D Camera Setup for Mobile Phones

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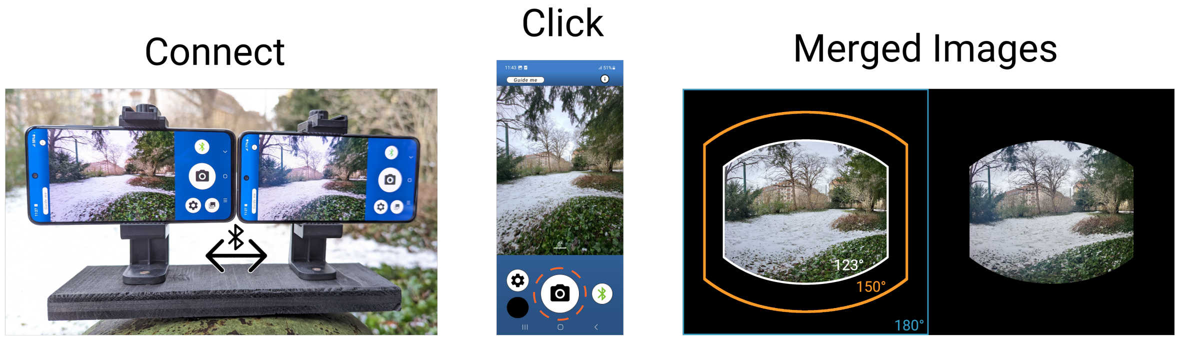

Figure 1: The Mobile VR Camera app is installed on two Samsung Galaxy S21 FE devices that are secured onto a custom-made mount. Both devices capture wide-angle photos simultaneously. These are transformed into an equirectangular image, transmitted to the other device and merged. The merged image also displays how a horizontal field of view change alters the result.

Abstract

Immersive media is becoming popular due to increased consumer access to virtual reality (VR) headsets. Mass adoption of 3D and immersive media may require devices similar to 2D phone cameras. Smartphones now feature wide-angle cameras with up to 150° field of view, approaching the 180° field of view in VR180 stereo photos. In this work, we use two smartphones with 123° wide-angle cameras and create a new app to capture immersive media in an equirectangular format for VR consumption. Our work is a proof of concept deploying current mobile devices to approach VR180 stereo photos with the available smartphone today.

Index Terms: Computing methodologies—Computer vision—Image and video acquisition—3D imaging;

1 Introduction

Since its introduction, photography has been mostly a medium viewed in 2D. Nevertheless, some companies already offer solutions to capture photos suitable for immersive VR, allowing for a wide-angled stereoscopic viewing experience. Regularly captured images, unfortunately, cannot be converted to allow for such immersive viewing experiences. The reason for this lies in the small field of view (FOV) of most cameras. If users want to create a wide-angled stereoscopic photo, they need to buy an extra, sometimes expensive, 180° or 360° camera. This, in combination with the fact that VR headsets remain relatively pricey, deters many people from looking into VR-focused photography. In our work, we alleviate the point of entry to some extent by offering a low-cost solution for immersive photo capture while allowing a larger resolution output than many current consumers solutions. Consequentially, it makes high quality VR180 stereo photography, up to the limitations of the FOV of the smartphone wide-angle lenses, available to more people.

Mobile VR Camera is an app for Android that easily converts an identical pair of smartphones into a stereoscopic camera system. Based on our tests, we recommend a wide-angle lens of the used phones of at least 110° FOV. Otherwise, the immersive effect of viewing the photo in a VR environment may be compromised due to a large area of missing image data. After connecting two phones via Bluetooth, photos can be taken by simply holding the devices towards your desired target and pressing the trigger button on one smartphone. We also built a specialized mounting bracket to ensure stability, repeatability and horizontal alignment. After taking the photos, the app creates an image suitable for viewing in VR.

2 Related Work

Today, purchasing expensive hardware is unavoidable in order to capture high-quality 180° or 360° VR stereo images in an instant shot. Many modern VR-cameras are still limited by their sensor resolution with often less than 4K horizontal content per eye for 180°. By utilizing two separate smartphones, the image quality can be greatly enhanced. Apple's smartphone devices have recently begun venturing into stereo content capturing under the name of spatial photos and videos. The iPhone captures the images and videos by using two of its cameras. By relying on only one wide-angle camera, the FOV of the merged result is limited by the camera with the lower FOV. This lowers the immersion. The distance between these two cameras is much shorter compared to the distance between the average human eyes which may cause an unpleasant viewing experience. It is usually recommended to capture real-world 3D content at around the adult human average interpupillary distance of 6.3cm. On Android devices, the app 3DSteroid Pro allows users to capture stereoscopic pictures by taking two photos with a single device by manually moving the phone. This method does not allow dynamic movements in the scene.

Our Mobile VR Camera cannot provide the same FOV and options as some standalone devices. Instead, it aims to provide an easy and reliable way to create wide-angled high resolution 3D images for users with two equal smartphones. Dynamic scenes can be captured. This was achieved by synchronizing the two devices via Bluetooth and by mounting them on a custom-built contraption. We screwed

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two mobile phone holders on a 250mm × 80mm × 20mm wooden plate at eyes distance between them (Figure 1). Each bracket allows users to customize the distance, clamps and rotation to accommodate various smartphone sizes. Using smartphones has benefits such as a high-quality image preview and IMUs to visualize a water scale, features which only few VR cameras have today.

3 Methodology

3.1 User-Centered Engineering

We followed a user-centered engineering approach [1–3]. Based on the project's start at which our target audience's needs were determined, an extensive research and market survey ensued (the "trawl for knowledge"), the requirements were formally documented, verified and an iterative development process followed to improve the user interactions, app design or necessary features.

Configuring the smartphone camera for wide-angle access proved to be a significant challenge, which triggered multiple discussions and a small survey. Many smartphones, such as the realme GT2 Pro with its 150° fisheye lens, did not allow the necessary API access. Eventually, we chose the Samsung Galaxy S21 FE for its modest pricing and the high-quality 123° wide-angle camera capability.

3.2 Engineering Concept

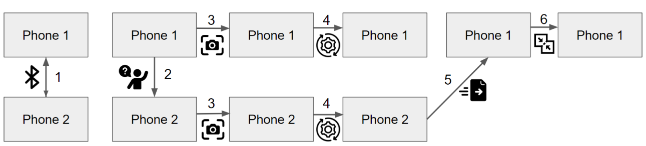

Figure 2: Main workflow of the application: 1 - Establish connection; 2 - Send capture request; 3 - Take photos (2 × 4000 × 3000 pixels); 4 - Process image; 5 - Send processed image; 6 - Merge images

For the camera, we aimed to provide a stereoscopic camera system with the ability to regulate exposure time, white-balance and focus distance as these are necessary for synchronization of two devices. Android Studio (Flamingo 2022.2.1 Patch 2) was used with the Android SDK 33 (Android 13) and the CameraX (1.3.0-beta01) and Camera2 libraries. CameraX serves as the rudimentary camera logic, while Camera2 allows for more advanced data access.

The access to a particular camera needs to be implemented by the phone manufacturer in the Hardware Abstraction Layer (HAL). If not, all physical cameras (on one side of the phone) will be bundled to one logical unit. Therefore, accessing a certain camera in Android can be troublesome. By utilizing the CameraX's zoom functionality, we were able to circumvent this issue and access the wide-angle camera. However, this workaround cannot be robustly assumed for arbitrary devices. The camera system itself works by creating a singleton object with the purpose to bind the lifecycle of cameras to an object that owns an Android application lifecycle. As only one camera can be active at a time, we exchange the currently active camera object that is bound. This is done by a setup function that is called every time the current focus inside or outside the app changes. We store all necessary camera data in a singleton object that remains constant across two camera instances. This allows easy access of camera-specific values across the application and between context switches. If specific camera capture modifiers like auto focus, auto white-balance, video stabilization or focus distance are modified, a synchronization object will handle the adjustment for the host and client phone. The options are saved within maps that contain the names of the capture modifier as a key and their corresponding value. These values are sent to the connected device for synchronization.

Before we can transmit data, we have to meet several requirements, such as obtaining the appropriate Android permissions for Camera, Microphone and Near Devices (Bluetooth), ensuring Bluetooth is enabled, and allowing the app to access the Bluetooth adapter, which is handled on startup.

To improve the user experience and capture visually appealing images, we created a manager that leverage the geomagnetic field sensor along with the accelerometer. It provides real-time feedback on the device's current rotation by showing a line just like a water-scale and the current rotation value. This is crucial in capturing images without slant, as viewing such images can lead to motion sickness. Other features include a gallery preview and sharing.

3.3 Image Conversion

To ensure that 3D photos can be viewed as 180° images in VR, we convert the captured perspective images into the equirectangular format (Figure 1). A key difference in the equirectangular format is the mapping onto a sphere, resulting in a spherical image. These images, when viewed in a VR environment, create the impression of a spherical space and can immerse users into the scene.

4 Discussion

The method of creating a 3D camera system for Android devices described in this paper should serve as a solid groundwork to further improve upon. The most important functionalities are implemented as well as some basic quality of life features. Future enhancements for the Mobile VR Camera could include the usage of AI to further enhance the user's immersion by widening the FOV as the majority of smartphones today are limited to a wide-angle lens of around 110°-120°. Support for video capture could be added to the application. The biggest hurdle for this feature is the synchronization between the videos. An easy solution of this issue would be to use a trigger that is independent from the phones themselves like starting the recording at a certain time stamp.

To allow these goals to come to fruition, we provide the free, open-source code repository under: `https://github.com/MobileVRCamera/MobileVRCamera`

5 Conclusion

In this work, we set out to enhance accessibility of VR180 stereo photography for a broader audience. Our effort was motivated by the realization that although VR photography offers immersive experiences, the challenging barriers to entry, such as costly hardware for high quality capturing, often dissuade creators. Therefore, we developed the Mobile VR Camera app as a user-friendly proof of concept solution to overcome these barriers. We have shown that it works well with pairs of modern off-the-shelf smartphones that implement the necessary access via the HAL described in section 3.2 to create high-quality, wide-angle spherical images up to the limitations of the current FOV of the smartphone's lenses which may increase over time. Furthermore, our undertaking should also point out to smartphone manufacturers that the addition of dual wide-angle field of view, ideally in interpupillary distance, can be quite an exciting feature, as we have shown with our setup. We are committed to the idea that VR photography should be widely accessible and provide immersive experiences for everyone, and we look forward to future advancements and innovations in this field. The Mobile VR Camera app is an example of our vision, and we are inviting others to expand on our work and participate in this transformational journey.

References

[1] J. Dick, E. Hull, and K. Jackson. *Requirements Engineering*. Springer, 2017.

[2] M. Richter and M. Flückiger. User-Centred Engineering. In *User-Centred Engineering*, pp. 11–24. Springer, 2014.

[3] S. Robertson and J. Robertson. *Mastering the Requirements Process: Getting Requirements Right*. Addison-Wesley, 2012.