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ARCritique: Supporting Remote Design Critique of Physical Artifacts through Collaborative Augmented Reality

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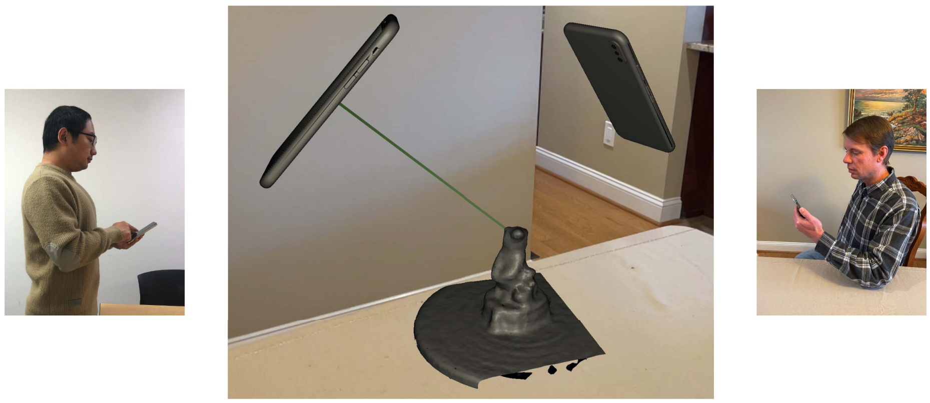

Figure 1: Two remote users holding smartphones view and interact with the same virtual object through ARCritique in a collaborative virtual environment. ARCritique allows them to point to the virtual model while maintaining awareness of collaborators.

Abstract

Design critique sessions require students and instructors to jointly view and discuss physical artifacts. However, in remote learning scenarios, available tools (such as videoconferencing) are insufficient due to ineffective, inefficient communication of spatial information. This paper presents ARCritique, a mobile augmented reality application that combines KinectFusion and ARKit to allow users to 1) scan artifacts and share the resulting 3D models, 2) view the model simultaneously in a shared virtual environment from remote physical locations, and 3) point to and draw on the model to aid communication. A preliminary evaluation of ARCritique revealed great potential for supporting remote design education.

Index Terms: Human-centered computing—Mixed / augmented reality; Human-centered computing—Collaborative and social computing—Collaborative and social computing systems and tools;

1 Introduction

Collaborative presentation and critique of physical artifacts are essential to the design process and studio model in many disciplines, such as Industrial Design (ID). In a conventional in-person session, the instructor and other students can communicate fluidly about the artifacts because of the shared space and ease of spatial referencing.

However, moving these critique sessions online to support remote learning is difficult, as it is challenging to give feedback on a physical object through remote communication tools. While using groupware like video calls can provide a real-time visual of a physical object, those who see the physical object through a computer screen cannot see the object at its true scale, cannot examine it from various angles, thus fail to perceive the object correctly through the transmitted visual. Furthermore, referring to locations, parts, or spatial characteristics of an object requires excessive descriptive language for the person without access to the artifact [3]. Moreover, both parties need additional verbal confirmation to ensure consensus on the point of interest.

There are a number of approaches to address the challenges of remote collaboration coming from the lack of shared perspectives, like perspective sharing using augmented reality headsets (e.g., [2]). However, existing systems focus on sharing the egocentric view of an on-site user and are limited in their ability to support communication and perspective control centered around a physical object.

We propose ARCritique, a handheld Augmented Reality (AR) application that supports remote collaboration by allowing its users to scan mockups and share the resulting 3D models, view the model simultaneously in a shared virtual environment from remote physical locations, and point to and draw on the model to aid communication. We performed a preliminary evaluation with an ID student and instructor and received promising comments. Although evaluated in a particular scenario, the application should be applicable to various use cases in other areas, such as architecture, urban planning, etc.

2 Application Design

ARCritique consists of two major components:

- A KinectFusion [4]-based processing algorithm that generates a virtual model based on the depth data captured by the phone;
- ARKit[1] working in conjunction with Photon Engine[2] to provide shared viewing and interaction.

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[1]https://developer.apple.com/augmented-reality/
[2]https://www.photonengine.com/

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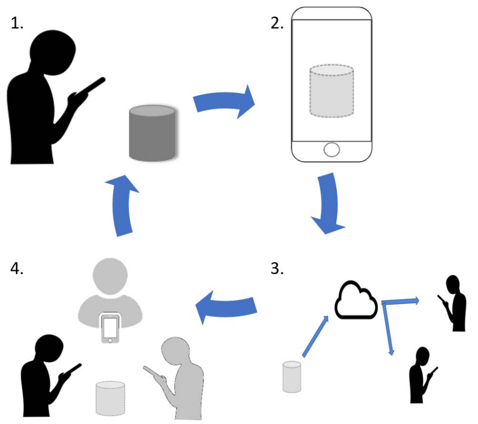

Figure 2: The iterative design cycle enabled by ARCritique.

Through these, we achieve an iterative design process shown in Figure 2:

1. User scans the physical artifact with their smartphone.
2. Once the program generates a virtual model, the user inspects the model's quality to decide whether they want to upload and share it or to re-scan and obtain a new model.
3. If accepted, the model is uploaded on a cloud server and is available for others to download.
4. Multiple users can jointly inspect the same model in AR even when they are remote and separated.

2.1 Model Preparation

To quickly obtain a virtual representation of a physical artifact, we need an online model generation algorithm. Another advantage of an online solution is that the user can observe the scanning process and refine details when they notice any deficiency in the current model. ARCritique uses KinectFusion to achieve this goal. The algorithm generates physical meshes based on 3D points defined by depth information and the six degrees of freedom (DoF) pose of the depth camera. Since iPhone X, any iPhone with FaceID technology is equipped with a TrueDepth camera[3] (a camera and infrared projector pair that can be used to create a depth map of a scene) and can therefore be used for this approach. One notable drawback is that the TrueDepth camera is located on the front side of the phone, meaning that the user has to hold the phone facing the physical object and loses access to the screen. A temporary solution is for the user to mirror or project the phone's screen during the scan process. In our implementation, the application uploads the points to a cloud server to generate the final model using Poisson surface reconstruction [1]. If the user decides to keep the model, it is automatically saved on the cloud server for others to access.

2.2 AR-Supported Collaborative Critique

The AR collaborative critique functionality is implemented through Unity[4], ARKit, and Photon Engine. Once users select a virtual model, they join an online session with all other users viewing the same model. The application uses ARKit and asks the user to move their phone around to capture the user's physical environment and detect a horizontal plane to place the virtual model. ARKit also handles six-DoF tracking of the camera device, providing the viewing user the freedom of seeing the model from any perspective. ARCritique synchronizes remote users in the same session by exchanging their poses relative to the model. Moreover, to aid awareness, the application also provides virtual phone models representing each collaborator, whose positions and orientations are constantly updated.

To exchange referencing information, a user can tap on the model on their phone's screen to cast a pointing ray, as shown in Figure 1. A virtual pointing ray will appear simultaneously on other collaborators' screens connecting the target location and the pointing user's phone model. In this way, users no longer have to use verbal communication and confirmation to ensure visual consensus. A drawing mode also allows users to sketch on the surface of the 3D model by dragging their finger over the model on the phone's screen.

[3]https://support.apple.com/en-us/HT208108

[4]https://unity.com/unity/features/arfoundation

3 Evaluation

We invited an ID student and an instructor at our university to test ARCritique and compare our application with Zoom, a videoconferencing tool they have used for remote critique sessions in the past. The student presented their physical design mockups to the instructor by sharing the scanned model and received comments to improve their design. Both participants had training sessions with the experimenter prior to the study session to familiarize themselves with the application. Since the application does not support audio communication, the student and the instructor communicated verbally through a Zoom call. To minimize interference and ensure ecological validity, the experimenter observed the critique session and recorded the meeting via Zoom and ARCritique. After the experiment session, the student completed a post-questionnaire asking about their experience with the AR application compared with their experience using Zoom. Follow-up interviews were also conducted with the student and the instructor separately.

While the result is preliminary due to the scale, the initial result was promising. The participants expressed favor for the application with comments like "*I was surprised by how natural it was to communicate around the AR object.*" or "*The ability to click on the model to point helped a lot with communication.*"

4 Conclusion and Future Work

We have presented ARCritique, a mobile AR application that facilitates design critique sessions around physical objects by enhancing spatial information communication. An initial evaluation suggests that our approach has merit, but further study is needed. Future experiments will aim to understand how the ability to do collaborative spatial referencing in shared AR space can enhance the effectiveness of communication about 3D objects over conventional collaboration approaches. We also plan to further refine ARCritique, expand its use to other design disciplines, and make it available more broadly.

Acknowledgments

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