RealityGit: Cross Reality Version Control of R&D Optical Workbench

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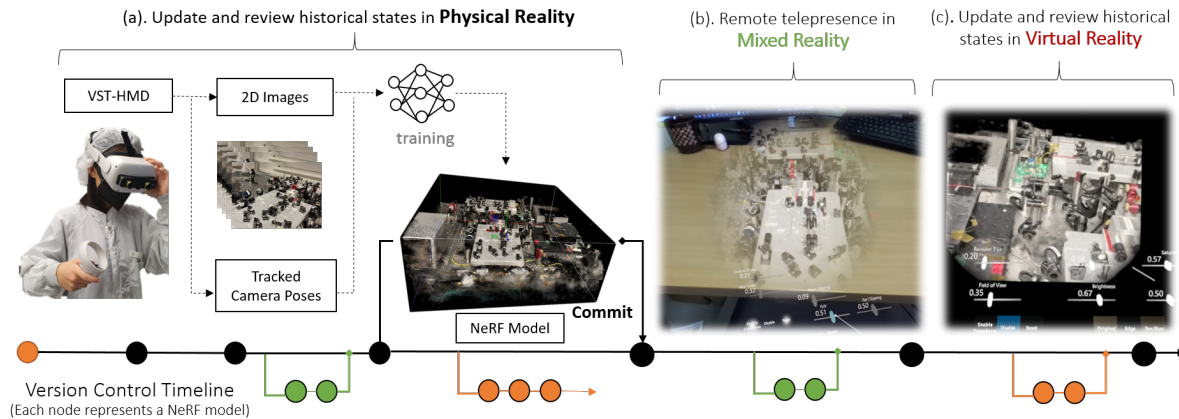[3] Computer Vision, Department of Informatics, Universität Hamburg

Figure 1: Illustration of the version control timeline of RealityGit, starting from (a), where a user wears a VST-HMD while physically present at the workbench. The VST-HMD saves the 3D states of the workbench by training a NeRF model and supplies these NeRF models to remote users or virtual users. (b) illustrates how remote users can contribute to the workflows by merging the current state of the NeRF model into their own workbench in MR. (c) illustrates how virtual users can contribute by performing assembly reviews and update tasks in immersive VR.

ABSTRACT

Multi-user collaboration at research and development (R&D) workbench in advanced optics laboratories involves updating and documenting the status of hundreds of components. Although there are abundant mixed reality (MR) systems to support the collaboration of spatially co-located users, limited methods are available to facilitate cooperation in the spatial-temporal domain. Inspired by the version control workflow used in software development, we propose RealityGit, a novel cross-reality (CR) system design that leverages the recent advancements of neural radiance fields (NeRF). We illustrate how the NeRF model can be used to channel users with different extended reality (XR) experiences by providing an accurate immersive visual documentation of the historical states of a complex R&D workbench. We demonstrate the feasibility of such a system through an implementation where users could contribute to the version control workflows by integrating historical NeRF scans into their MR devices or providing status reviews by annotating or editing a NeRF model in virtual reality (VR).

Index Terms: Mixed Reality—Version Control—Neural Radiance Fields—Human-centered computing;

1 INTRODUCTION

Research and development (R&D) workbench such as those in advanced optics laboratories presents a highly complex workspace with a large number of assembly components. This introduces a

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demanding spatial memory re-call challenge for researchers to keep track of each historical state of the system development process, especially when it comes to large projects where multiple users need to collaborate on a workbench at different times. Although different visualizations of the setups such as a 3D computer-aided design (CAD) model could be brought to immersive mixed reality (MR) to assist users with their workflows, the exact details of the workspace are often too complex to be accurately modeled in the traditional rasterization pipelines. Moreover, at R&D laboratories where iterative trial-and-error approaches are taken for rapid system prototyping, it is unrealistic to manually model every single step through conventional 3D modeling software.

To enable more efficient workflows when building setups at R&D workbench, we propose RealityGit, a cross reality (CR) version control system that could bring together users at different spatial and temporal locations with one unified version control timeline. As Figure 1 illustrates, the timeline records the accurate states of reality by converting the 2D image sequences captured by a video see-through head-mounted display (VST-HMD) to a neural radiance field (NeRF) [3]. Each NeRF model can be accessed by users at different points in time through different devices at different locations. For example, the NeRF model can be blended into a remote user's field of view (FoV) at a real-world scale through an immersive MR device to provide a telepresence experience, where the remote user could also contribute to the physical setups. Additionally, users in VR can be engaged as well by reviewing the historical state of the development process while making suggestions for design updates and revisions. Finally, we present two system demonstrations showing the feasibility of our designs where both real-time MR and VR NeRF experiences are possible using the instant neural graphics primitives (instant-ngp) [3] as training and rendering engine, and the Magic NeRF Lens framework as rendering and interaction framework [2].
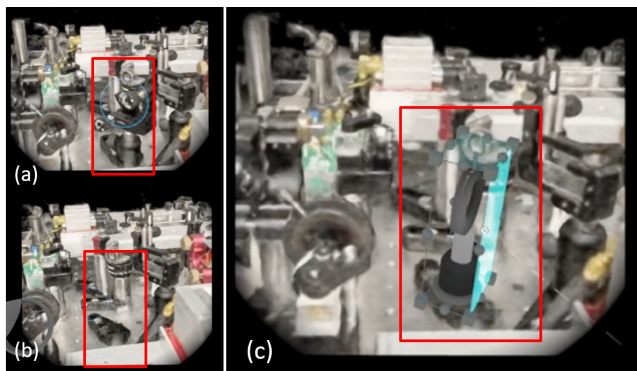
Figure 2: Application screenshots showing how a NeRF model can be asynchronously modified and updated in VR, with (a) showing the NeRF model before modification, and (b) showing the NeRF model after an optical component was erased using 3D NeRF drawing effect proposed in [2], and (c) showing how a virtual optical component is integrated onto the NeRF model to illustrate new design suggestions.

2 SYSTEM DESIGN

2.1 Application Domain

As revealed by Li et.al, a VST-HMD at optics laboratories is not only how users could better interact with the computer, but also a necessary scientific instrument to protect users' eyes from laser radiation [1]. As a result, future researchers working with high power and wide bandwidth laser setups will very likely use a VST-HMD all the time while working by the optical workbench. Moreover, due to various hazards (e.g. laser radiation, fiber safety, etc), access to these laboratories can be limited and expensive. Therefore, cross-reality (CR) systems are highly relevant to organize the collaborative R&D process while unifying users in different spatial and temporal realities.

2.2 The CR Version Control Workflows

Figure 1 presents an overview of the version control timeline of RealityGit with each node containing a 3D representation of the optical workbench. We distinguish 3 different node types, with a black node containing a NeRF model which records the actual physical state of the workbench, a green node containing a NeRF model edited or annotated by a remote user in real-time, and the orange nodes containing 3D representations asynchronously designed in VR.

An R&D project at advanced optics laboratories typically begins with a virtual 3D representation, such as a CAD model illustrating the initial design of the setup. Then, users start the initial prototyping processes at the physical optical workbench where users are equipped with a VST-HMD all the time to meet the laser health and safety standard. The VST-HMD can document each historical milestone by converting the 2D images captured by the see-through camera to a NeRF model upon the user's request. When a remote user can not be physically present at the laboratories, an MR branch can be opened, through which the user can annotate and edit the workbench through the recorded NeRF model to communicate with the onsite user synchronously. The onsite user can pull the change suggestions from the remote users and reconfigure the physical setup accordingly. As shown in Figure 1 (b), if the remote user also wears a stereoscopic VST-HMD, the NeRF model can display the remote scenario by seamlessly merging the NeRF model with the workbench of the remote user, potentially achieving realistic telepresence effects with the remote user having high situational awareness.

At different points in time, a VR branch can be opened asynchronously for virtual users to review different historical states of the setup. In the VR branch, users can edit and modify the physical design and create new designs based on the current or historical state of the physical setup rather than starting a new CAD modeling process from scratch. Figure 2 presents application screenshots of how a NeRF model could be asynchronously modified in the VR branch. To modify a NeRF model, the user can use the 3D NeRF drawing technique implemented by Li et.al in the Magic NeRF Lens framework [2] to dynamically and accurately erase a portion of the NeRF model. A virtual model can then be integrated and blended into the original NeRF model to demonstrate suggestions for future physical implementations, as shown in Figure 2 (c).

Similar to typical version control workflows, users working on the main branch (the actual physical workbench) can check out the designs of different users from the MR and VR branch, as well as the historical states of the physical setup in the main branch. Advanced version control features such as a comparison of the changes between the current physical state and a historical state can be potentially achieved by merging a historical NeRF model back to reality through the VST-HMD. Changes can be revealed spatially by comparing the images captured by the VST-HMD with the rendered NeRF images using techniques such as structural similarity index (SSIM).

2.3 System Demonstration

To demonstrate the feasibility of our design, we present two immersive XR experiences. Both experiences use the magic NeRF lens framework implemented by Li et.al [2], where users can manipulate, edit, and update the NeRF model in immersive VR. The framework can be run on the Unity game engine version 2019.4 and uses instant-nap [3] as the backbone for NeRF training and rendering. To allow using the magic NeRF lens framework for users in immersive MR, we extend the previous system with a ZED Mini stereoscopic camera which can be mounted on an Oculus Quest 2 VR headset to provide high-resolution VST experiences. Both VR and MR NeRF experiences can be run in real-time at high resolution on a high-end graphics device such as an RTX 3090 GPU.

3 DISCUSSION AND CONCLUSION

The possibility to collaborate across different spatial and temporal realities has the potential to significantly improve the efficiency of R&D workflows in empirical settings. For example, at high-power laser laboratories, onsite users' view of the workbench can be restricted, as users need to avoid moving their heads at the same height level of the optical workbench to prevent direct exposure to primary laser radiation. However, remote users or virtual users can freely navigate within the workbench through the NeRF model to perform close inspection and design tasks that are not possible in physical reality. Although this submission mainly targets users at advanced optics laboratories, our CR design can potentially benefit users in other XR domains, such as electronic engineering, industrial manufacturing, and architectural planning alike.

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