Johannes Kretzschmar, Clara Henkel, Falko Sojka, Jari Domke, Thomas Kaiser, Christian Helgert and Thomas Pertsch

XR Twin Lab: an Open-Source Toolbox for XR Remote Access to Experimental Setups in Photonics based on Web Technologies

Abstract

Remote labs are a trendsetting way of teaching, communicating, and experiencing science as well as enabling collaborative work. Unfortunately, the implementation of remote access involves cost-intensive development or at least requires a certain technical skill set. To establish remote labs across disciplines, especially outside the field of IT and engineering, the technical access threshold must be low enough to support their self-contained implementation by researchers, assistants, and technical staff. Here, we demonstrate one possibility with the open-source toolbox XR Twin Lab for the research field of Photonics. The XR Twin Lab (XRTL) provides a modular way of building a web-based application to control optical experimental setups with the integration of VR and AR endpoints.

Keywords

Remote Lab, Web Technologies, Mixed Reality

1 Introduction

There has been increased development of new teaching concepts involving digital technologies, especially shaped by the ongoing COVID pandemic. In the research field of photonics at Friedrich Schiller University, Jena (FSU), this development is being driven forward by three partners: the international and interdisciplinary graduate school Max Planck School of Photonics (MPSP) has set up a digital teaching lab to test and implement cross-site pilot projects in digital teaching (Kaiser, 2021). The DAAD-funded project digiPHOTON aims to open the master's degree course in photonics at the FSU to remote students. One particular task hereby is to make practical content and laboratory experiments accessible. The photonics makerspace "Lichtwerkstatt", a BMBF-funded project to establish open innovation processes in the photonics industry (Zakoth, 2019), offers space, tools, and knowledge for community-driven open-source development. One of the many projects (Kretzschmar, 2021) accomplished over the last year in cooperation with the MPSP and digiPHOTON is the remote lab framework XRTwinLab (XRTL), which we would like to present here.

2 Implementation

To minimize the technical requirements for users, such as operating systems or runtime environments, XRTL is implemented as a Single Page Application (SPA) in JavaScript and can be executed by any ES6-compatible web browser. The steep learning curve of the script language JavaScript allows non-professional developers like teaching staff, researchers, or students to adapt applications to their use cases. Using the open-source framework React, JavaScript components can be directly mapped to corresponding counterparts in experimental setups. This emphasizes the modularity and adaptability throughout XRTL. The server application is developed accordingly in JavaScript and runs in a node.JS environment to ensure a uniform technology stack, as shown in Figure 1. On the experiment side, lab components are equipped with motorized attachments or sensors, which are connected to ESP32-microcontroller boards, which are capable of Wi-Fi connections. To maximize the benefits of XRTL, the repository is intended to be a growing resource of remotely accessible lab components, such as 3D-printable models, PCB designs, and source codes for using existing interfaces. The communication and synchronization between the client(s) and experiment are event-driven using the Socket.IO communication protocol, which is based on web sockets. To further enable collaborative work and live feedback, the camera and microphone feeds of the users and experiment are integrated with WebRTC, a protocol for real-time communication.

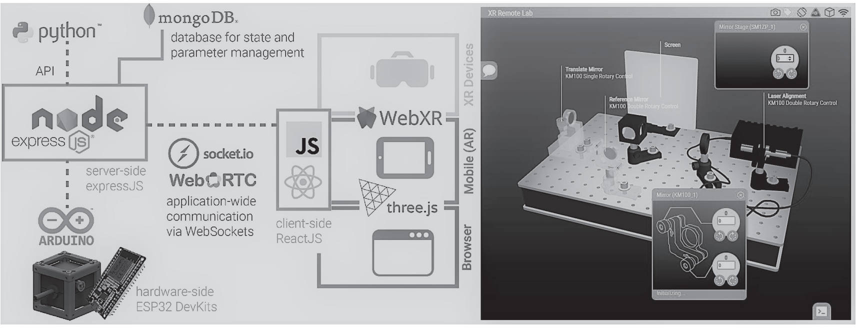

Figure 1: Architecture and Technology Stack with Screenshot of XRTL

We want to design the experience of remote accessing an experiment as closely as possible to real lab work. This supports learning in workflows in a lab and communication in collaborative work processes. Therefore, we focused in particular on the integration of Extended Reality (XR) visualizations and functionalities. With the JavaScript library Three.JS and WebXR, we can show and augment an interactive 3D model of components and setups in a collaborative virtual room.

We finished a functional prototype controlling a Michelson-Interferometer students kit from Thorlabs. In the future, we will test the modular adaptability of our platform regarding its integration into the modular optics toolbox UC2 (Diederich, 2021) and current research experiments from our partners at the FSU and MPSP. We will evaluate the feasibility of XRTL integration under various conditions as well as the user experience of the application itself, especially comparing the browser-only, and augmented and virtual representation.

References

D. Zakoth, S. Best, R. Geiß, C. Helgert, P. Lutzke et al. (2019) Open Source Photonics at the Abbe School of Photonics: How Makerspaces foster open innovation processes at universities, 15th Conference on Education and Training in Optics and Photonics: ETOP2019, 2019, Quebec City, Quebec, Canada

B. Diederich, R. Lachmann, S. Carlstedt et al. (2020) A versatile and customizable low-cost 3D-printed open standard for microscopic imaging. Nat Commun 11, 5979 (2020).

T. Kaiser, T. Lin, J. Kretzschmar, F. Sojka, J. Michel, C. Helgert, R. Geiss, T. Pertsch, and A. Tünnermann (2021) Digital Teaching in Photonics – new possibilities for Labwork Training Programs, in Education and Training in Optics and Photonics Conference 2021, A. Danner, A. Poulin-Girard, and N. Wong, eds., OSA Technical Digest (Optical Society of America, 2021), paper F2B.7.

J. Kretzschmar, S. Best, D. Zakoth, H. Voigt, K. Li, T. Kaiser, R. Geiss, C. Helgert, and T. Pertsch (2021) Utilizing Open Spaces for community-driven Development of XR Teaching Applications in Photonics, in Education and Training in Optics and Photonics Conference 2021, A. Danner, A. Poulin-Girard, and N. Wong, eds., OSA Technical Digest (Optical Society of America, 2021), paper F1B.7.

Authors

Johannes Kretzschmar
Institute of Applied Physics,
Friedrich Schiller University Jena
Albert-Einstein-Str. 15,
07745 Jena, Germany
johannes.kretzschmar@uni-jena.de

Clara Henkel
Abbe School of Photonics
Albert-Einstein-Str. 6,
07745 Jena, Germany
clara.henkel@uni-jena.de

Falko Sojka
Abbe School of Photonics
Albert-Einstein-Str. 6,
07745 Jena, Germany
falko.sojka@uni-jena.de

Jari Domke
Abbe School of Photonics
Albert-Einstein-Str. 6,
07745 Jena, Germany
jari.domke@uni-jena.de

Thomas Kaiser
Max Planck School of Photonics
Hans-Knöll-Str. 1,
07745 Jena, Germany
thomas.kaiser.1@uni-jena.de

Christian Helgert
Abbe Center of Photonics
Albert-Einstein-Str. 6,
07745 Jena, Germany
christian.helgert@uni-jena.de

Thomas Pertsch
Institute of Applied Physics,
Friedrich Schiller University Jena
Albert-Einstein-Str. 15,
07745 Jena, Germany
thomas.pertsch@uni-jena.de