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# Distributing cryo-ET education with WebGL and WebXR technologies.

Matthew Larson[1] and Elizabeth Wright[2]

[1]Cryo-Electron Microscopy Research Center, Department of Biochemistry, University of Wisconsin, Madison, WI, USA, Madison, Wisconsin, United States, [2]Department of Biochemistry, University of Wisconsin-Madison, Madison, Wisconsin, United States

Cryo-electron tomography (cryo-ET) excels at visualizing high-resolution three-dimensional structures while preserving the biological context of the sample. For a cell biologist, cryo-ET offers the best possible structural preservation with current technologies (1). Targets such as pleomorphic virus samples inapplicable to single particle image analysis (SPA) are often excellent targets for cryo-ET studies. Cryo-ET techniques have visualized the ultrastructure of the immature HIV-1 virion (2-4). Cryo-ET has also captured dynamic processes of viral assembly for the respiratory syncytial virus (RSV) (5), and macromolecular assemblies (6), and trafficking of cargo through nuclear pore complexes as evidenced by snapshots of structures at different points of the process (7).

A new web portal, Cryo-Electron Tomography Online or CETO, will provide engaging online training and protocols for cryo-ET imaging and interactive content for the cryo-ET community. Developments with WebGL and WebXR technologies support new methods for the distribution of interactive online educational content. BabylonJS (8) is an API for developing Javascript or Typescript-based interactive content that can be added to an HTML document. BabylonJS is being incorporated in a variety of 3D scientific visualizations including a protein structure viewer (9) and CT-based vascular models (10). Consumer-level headsets such as the Oculus Quest now support WebXR and provide next-generation hand-tracking with 26 degree-of-freedom poses. Hand-tracking provides accurate, low-jitter estimates of hand poses that naturally integrate with training experiences. These features provide a base for web-accessible training content for cryo-electron tomography education built on the BabylonJS toolkit.

The CETO web portal at https://ceto.wisc.edu will host the content as individual learning modules. Content is managed by members of the UW-Madison Cryo-EM Research Center (CEMRC) and Midwest Center for Cryo-Electron Tomography (MCCET). CETO provides training material for cryo-ET imaging, interactive content on web-browsers and augmented reality devices, and engagement with the cryo-ET community via forums and webinars.

Within CETO, several virtual laboratory modules have been designed to teach theory and practical operation protocols for cryo-EM and cryo-ET labs. Efforts are underway to transition existing transmission electron microscopy (TEM) lessons to be three-dimensional (3D) interactive training experiences. A training lesson features multi-component 3D models, step-by-step feedback, and collaborative learning sessions. CETO provides active content for K-12 and higher-education teachers, instructors, and other extension educators who seek tools to engage remote trainees as an alternative solution to hands-on classroom teaching and laboratory investigations. The website incorporates interactive 3D training experiences with multi-component 3D models, step-by-step feedback, and collaborative learning sessions. Learning objectives are reinforced with skill progression and tracking on areas where trainees may struggle with content. This resource will act as a collaborative learning portal for making cryo-ET content accessible to the broader research and engage the public audience.

Individual 3D models are developed in Blender (11) based on real-world objects and kept as a GL Transmission Format (glTF), a royalty-free specification for efficient transmission of 3D scenes and models. Additionally, we will distribute 3D models in the Filmbox (FBX) format supported by common 3D graphics engines. These models and the associated content will be disseminated online at http://github.com/wright-cemrc-projects.

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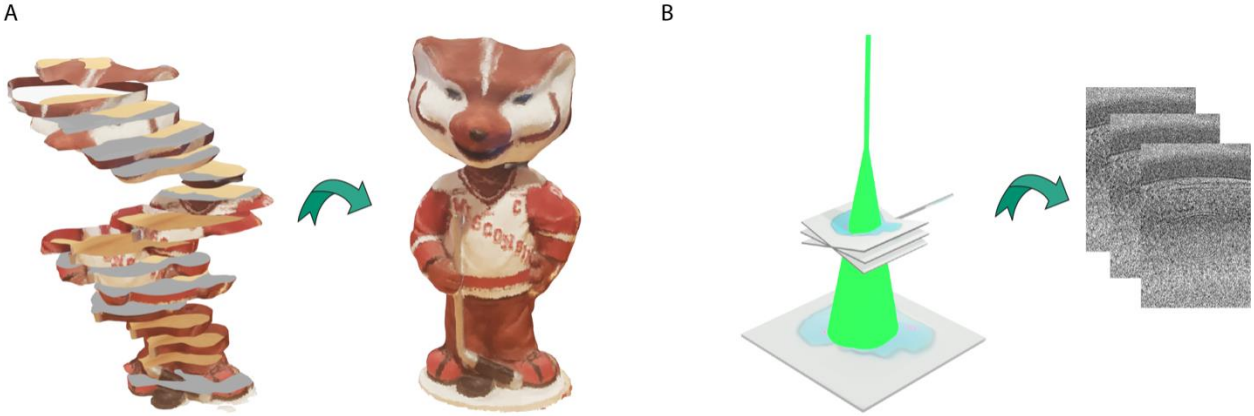


Figure 1. Figure 1: A tomographic reconstruction of UW-Madison's Bucky as a 3D volume from a series of image slices (A). In cryo-electron tomography, detailed models of frozen biological samples are reconstructed from projected images on a detector plate recorded at a series of tilt angles.

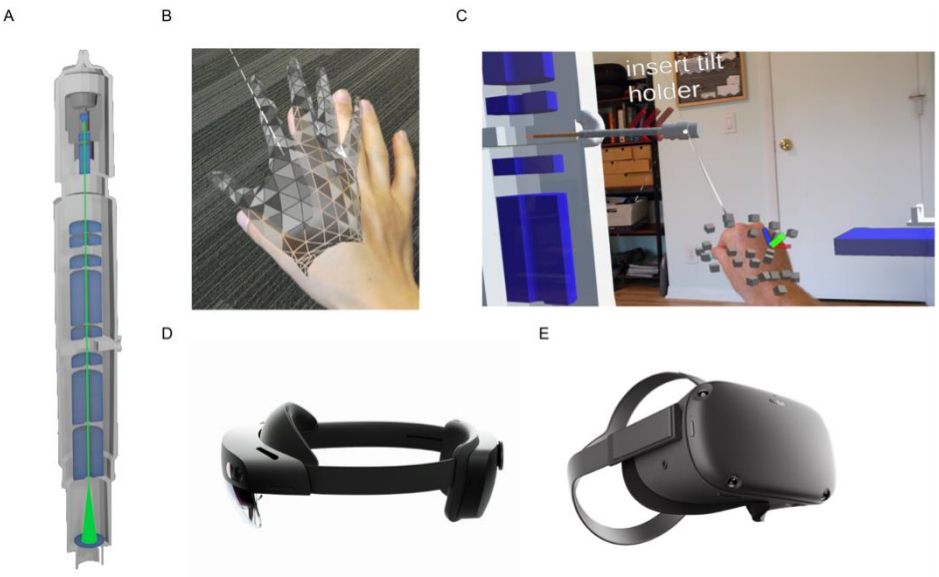


Figure 2. Figure 2: 3D models and content can be embedded in the web portal for virtual lab content . The 3D models such as the TEM column above can be created in open-source software such as Blender and exported as glTF format to be included in WebXR components (A). Articulated hand-tracking is a new input modality possible with the latest generation of devices (B). We are testing using the hand-tracking as an intuitive way to engage with training simulations such as loading a TEM column with a sample. Here shown through the

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front-facing camera of the Microsoft HoloLens 2 (C). WebXR content can be viewed in web browsers, and also with AR/VR headsets such as the Microsoft Hololens 2 (D), Oculus Quest (E).

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