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Idaho National Laboratory

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ABSTRACT

Mixed reality technology is being used across Idaho National Laboratory (INL) to enhance training and workforce development. Projects involving mixed reality such as lockout/tagout, the Industrial Control System Laboratory, and a Department of Defense microreactor demonstration have benefited from these innovative approaches. Several key concerns exist with integrating this new technology, including ease of use, ease of setup, and maintenance through the lifecycle. These aspects need to be properly addressed to ensure that this technology remains attractive and useful to operations teams as well as engineers and researchers at INL. Primarily, this requires buy-in from information technology management, designing software/hardware-agnostic tools, and reducing friction with technology integration. To be successful, regular operational use of this new and unfamiliar technology will require straightforward user interfaces, simple setup processes, and feature-rich experiences that reduce the time needed to benefit from the technology. INL is improving its toolset to allow for a streamlined deployment and use of mixed reality technologies that are directly available to researchers and engineers.

OVERVIEW OF MIXED REALITY USE CASES IN THE WORKSPACE

Lockout/Tagout

Lockout/tagout is a safety procedure used to ensure that maintenance workers and operators have complete control over the hazardous energy sources they encounter while working. It involves physically locking down the ability to activate energy sources and tagging them to ensure it is easy to identify which energies should not be activated during maintenance. It is a crucial procedure at Idaho National Laboratory (INL) where various types of hazards exist, ranging from radiation, electricity, and pressurized water. These hazards, if not properly handled, can result in serious injury or death.

INL trains hundreds of workers on lockout/tagout every month, and it is an essential component for employee safety in the workplace. Challenges of the current training practices include retention of material after yearly refreshers, nonexistent equipment-specific training, and costly one-on-one instructor training and testing. Yearly refreshers are required for lockout/tagout and typically involve a web-based test as well as an in-person practical on a physical mockup called the *closed-loop system*, as shown in Figure 1. While yearly refreshers are important, issues arise when the physical mockup test is the same every year. Taking the same test leads to memorization, which can result in poor retention, but it is difficult to change a physical mockup to provide a novel use case. Using mixed reality, we can mockup the physical system and easily create scenarios that meet the same criteria but are dynamically generated to prevent “click through”, a situation where users memorize the correct actions to take and perform them without retaining the core understanding of lockout/tagout.

It is usually infeasible to allow a researcher to train on lockout/tagout using the equipment in their everyday work. The equipment is often in use, and downtime for training creates delays and increases costs, hence the one-size-fits-all architecture of training with a physical closed-loop system. Being able to train on the equipment that the researchers use without the need of a physical mockup would allow researchers to understand the lockout/tagout responsibilities on their day-to-day equipment. Mixed reality can address this challenge and at the same time provide higher-quality training without the cost incurred by stopping work.

There are other issues with high-throughput training that mixed reality could address. There is a limited number of instructors and physical mockups for testing. The lockout/tagout training requires a one-on-one basis with an instructor, which is costly. Also, balancing schedules on a physical mockup can be difficult. Mixed reality allows students to practice on a virtual simulator that improves retention with a very low hardware cost. It also allows for remote proctoring, which alleviates the current one-on-one architecture. A single instructor could evaluate multiple exams at once from a remote location, if desired. Additionally, each instructor has a different measure of success and is subject to their own biases when grading practicals. The mixed reality platform can enforce a consistent grading criterion, which can lead to fair performance assessments not subject to instructor bias.

Instructors have responded favorably to this technology because of these benefits. Figure 2 shows a mixed reality pilot program that is underway at INL to assess mixed reality's effect on retention and student performance.

Figure 1. Physical "Closed-Loop System" for Lockout/Tagout.

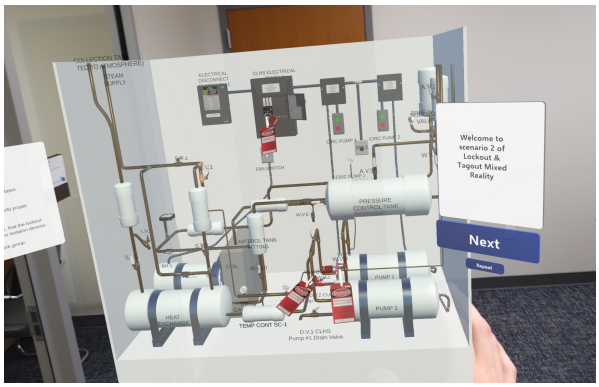

Figure 2. Virtual "Closed-Loop System" for Lockout/Tagout in Mixed Reality.

Industrial Control Systems Controls Laboratory

At INL, the Integrated Cybersecurity and Energy Resilience (ICS-CELR) program is pioneering the use of mixed reality to fortify national security and advance workforce development. The ICS-CELR program is dedicated to protecting critical infrastructure and industrial control systems (ICSs) from cyber threats by developing cutting-edge solutions and providing comprehensive training for cybersecurity professionals.

By incorporating mixed reality, INL has created immersive and interactive training environments that mimic real-world cyberattack scenarios. The environments allow trainees to experience and respond to simulated cyber incidents in a controlled setting, significantly enhancing their preparedness and decision-making skills. The realistic simulations provided by mixed reality not only improve engagement but also facilitate a deeper understanding of complex cybersecurity concepts and strategies.

A key emphasis of the ICS-CELR program is creating user-friendly training modules that are easy to set up and maintain. The integration of software/hardware-agnostic tools ensures that these training solutions can be seamlessly adopted by various departments and personnel, regardless of their technical expertise.

The success of the ICS-CELR program in using mixed reality technologies highlights the importance of innovative training solutions for enhancing cybersecurity resilience. By providing a dynamic and engaging training platform, INL not only accelerates the development of cybersecurity skills but also enables the rapid iteration and refinement of defensive strategies. This approach aligns with INL's

commitment to reducing iteration time on complex designs and training scenarios, ultimately leading to more effective and efficient workforce development.

As INL continues to enhance its toolset, it remains focused on delivering streamlined and impactful mixed reality experiences that directly benefit the national security sector. The ICS-CELR program exemplifies how XR technology can be harnessed to create a more resilient and capable cybersecurity workforce, reinforcing INL's role as a leader in innovation and excellence.

Figure 3. A Physical Skid in the Oil and Natural Gas Sector.

Figure 4. A Virtual Skid in the Oil and Natural Gas Sector.

Department of Defense Microreactor

Microreactors have received lots of attention for their small size, ease of manufacturing, utility, and reduced cost compared to traditional nuclear power plants [1]. Creating process flows for fueling operations that can be easily communicated to regulators and stakeholders is a difficult challenge for the new reactor design and construction process. INL has created a mixed reality fueling simulator that allows operators to test new processes and understand how fueling will happen with various facility and radiation control requirements. This simulator allows the operators to develop high-fidelity procedures months before a physical mockup is available. Changes in the reactor and fueling design are also more easily implemented in this environment, allowing for rapid feedback and design testing.

While this simulator is not widely available, its development offered important lessons for what operators are looking for when using novel technologies to solve problems in their day-to-day activities. Users of the mixed reality hardware, regardless of their discipline, expect the simulation to allow them to do several basic things, including repositioning the model, interacting comfortably with all aspects of the model, and being clear on which model they are viewing as parts of the model are updated.

Figure 5. Rendering of a Department of Defense Microreactor Transport.

GROUNDWORK FOR INTEGRATION

Hardware/Software Agnosticism and Lifecycle

An important question that customers and internal groups have regarding these technologies is what the long-term support and updating pipeline look like. Workers need to be able to use the headset that is appropriate for their work and have the software they need to perform their work. At INL, mixed reality applications are designed and developed in a way that is as hardware and software agnostic as possible. Using open standards such as OpenXR, we can provide support for many kinds of hardware, including hardware that is yet to be released, in a short amount of time. Mixed reality hardware evolves quickly, and almost every year a new headset is developed that provides better clarity or field of view or better interactions that are of interest to researchers. Adopting these open standards and writing software agnostic apps, we can ensure the longevity of mixed reality assets that are built and guarantee continued support for newer hardware and software at a low cost.

An example of this effort to be hardware and software agnostic is the lockout/tagout training pilot program. We migrated the entire training scenario from Microsoft HoloLens 2, which it was designed and developed on, to Meta Quest 3 in less than 48 hours, proving our ability to rapidly support new hardware as needed. In addition, we have developed a process for software sharing called extended reality adaptive interactions (XRAI). It allows important features to be easily transferred between projects and platforms, allowing features that customers have funded to be migrated to new projects, increasing the feature set we can offer without increasing cost.

Hardware Support from Information Management

One of the largest hurdles for getting value out of mixed reality devices is being able to connect them to data sources that matter. INL has a security posture that must be maintained, which makes getting hardware support on the network difficult. Often, projects that involve mixed reality applications are one-time use. For example, a dataset that was approved for headsets for one project may become outdated, so the headsets quickly lose utility, and the cost of bringing new data online and approved is arduous. To mitigate this issue, we have done the groundwork necessary to get hardware support on our internal network, which provides an opportunity for quickly updating data using our digital twin platform, DeepLynx, and keeping mixed reality viable for ongoing project needs [2]. Hardware support and continued access to company resources are essential for the continued utility of this technology. Getting information management onboard is an often-overlooked complexity of mixed reality that will need to be

addressed for long-term investment to be fruitful.

Reducing Friction with Technology Integration

Usually, as models are updated during the design process, each new design is manually updated and pushed to the mixed reality application that is then used for design reviews or training. While this process works, and models can usually be updated in a matter of hours, friction can occur in this process when design changes happen frequently. Often, multiple design updates cannot be done quickly enough to meet the needs of the customer. As such, we are developing software, currently called Model Viewer, that allows customers to update their own designs.

The high-level workflow, shown in Figure 6, starts with the user going to a web portal, then uploading their CAD model, waiting for the model to automatically be parsed by and ingested into DeepLynx (INL's digital twin management software), and finally deploying that model to a headset or viewing it on the DeepLynx website. This process allows customers complete control and access so they can perform design reviews on updated designs without needing to wait on resources to update an application manually. This will significantly reduce the need to develop commonly requested tools or features, allowing customers to invest in better mixed reality interactions and optimizations. The development of these tools such as Model Viewer and DeepLynx enables faster access to the resources required to speed up designs and other work, increasing the opportunity for customers to include new technologies into their workflow.

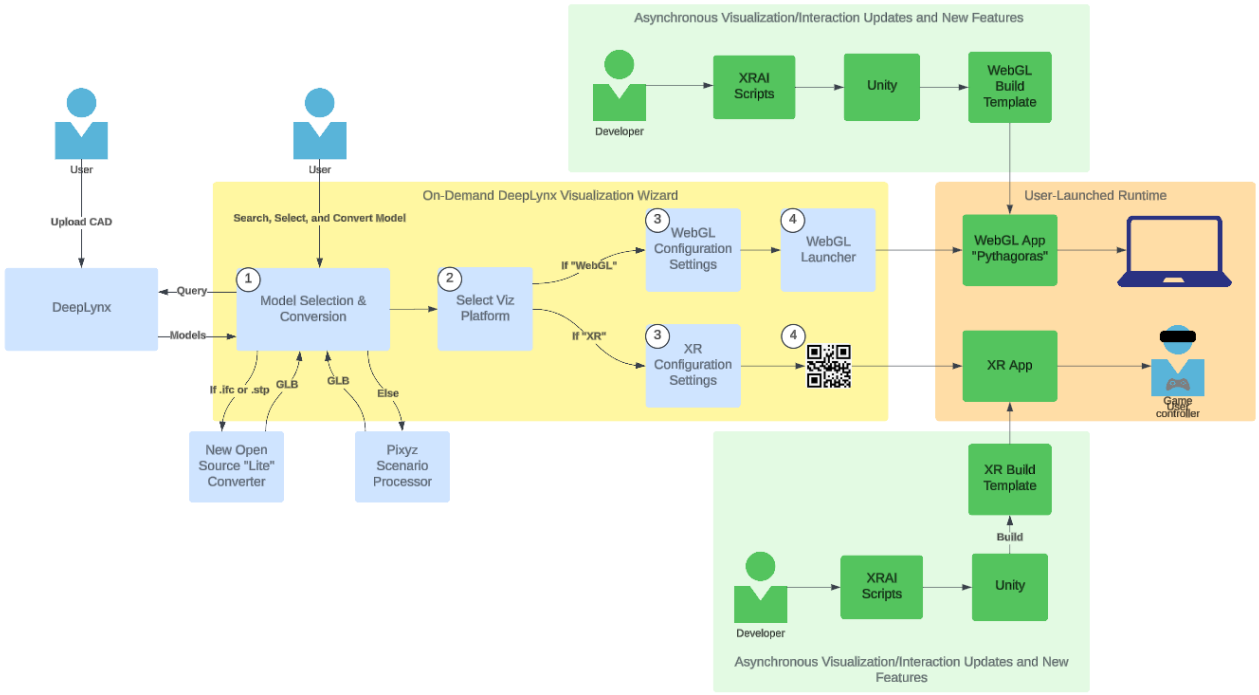

Figure 6. Model Viewer Architecture.

CONCLUSION

The integration of mixed reality technologies into lockout/tagout procedures, the Integrated Cybersecurity and Energy Resilience (ICS-CELR) program, and Department of Defense microreactor demonstrations at Idaho National Laboratory (INL) is revolutionizing training and workforce development. These initiatives

demonstrate the significant advantages of mixed reality in creating immersive, interactive, and flexible training environments that enhance user engagement, improve knowledge retention, and facilitate the rapid iteration of complex designs.

By addressing key concerns such as ease of use, setup, and maintenance, INL is successfully minimizing friction and reducing the time required to deploy mixed reality capabilities. This has been achieved through strategic collaboration with information technology management, the adoption of hardware/software-agnostic tools, and the development of platforms such as the Model Viewer that empower users to update and manage their own designs.

As INL continues to enhance its XR toolset, it remains focused on delivering streamlined, impactful, and scalable mixed reality experiences that directly benefit researchers and engineers. The lessons learned and the groundwork laid for hardware support and software sharing ensure that these technologies will remain viable and valuable as they evolve.

The successful integration of mixed reality technologies at INL underscores the potential of these tools to transform traditional training and operational processes, ultimately leading to more effective and efficient workforce development. By maintaining a commitment to innovation and excellence, INL is poised to remain at the forefront of technological advancements that support industrial progress.

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