MIXED REALITY VISUALIZATION OF RADIATION IMAGES FOR NUCLEAR INSPECTION

O. Pakari[1,*], R. Lopez[1], S.D. Clarke[1], and S.A. Pozzi[1]
[1]*Department of Nuclear Engineering and Radiological Sciences, University of Michigan, Ann Arbor, MI 48109*
[*]*pakari@umich.edu*

ABSTRACT

Mixed reality technologies using head-mounted devices promise an intuitive way of presenting complex data directly as holographic visual impressions to a user. We discuss the potential application of such a device, the Microsoft HoloLens2, with the information obtained from a neutron and gamma-ray imaging detector in the context of nuclear safeguards. The detector used is the Handheld Dual Particle Imager (H2DPI) developed at the University of Michigan. It utilizes a compact array of organic scintillators (organic glass or stilbene) and inorganic scintillators (CeBr3) set in a geometry optimized for radiation imaging, i.e., the system registers double scatter events in two detector volumes and reconstructs the radiation incidence direction via backprojection algorithms. The thereby obtained radiation images are typically interpreted on computer screen, in diagrams showing intensity over angular space around the detector. We present recent developments in translating said angular information into the HoloLens2 smart glasses, thus reducing the user's interpretation requirements and potentially providing a more intuitive impression of the radiation source location. The HoloLens2 provides a real time spatial mesh of its surroundings from cameras and depth sensors which we intersect with the radiation image to create a 3D impression of where radiation is streaming from. We discuss the implementation from detector signals to mixed reality visualization and speculate as to how mixed reality technology could be incorporated into inspection scenarios to improve workflow and lower radiation exposure.

INTRODUCTION

Radiation source localization and special nuclear material verification require radiation detection tools and highly trained inspectors to meet the IAEA's standards with respect to its safeguards and nonproliferation mission. Scatter-based radiation imaging systems can provide a wide range of relevant information, such as radiation incidence direction for source search or location verification, energy spectra for material characterization or identification, and neutron detection for fissile isotope signatures. Recently, we developed a hand-held dual particle imager, called H2DPI, at the University of Michigan that offers compact gamma ray and fast neutron imaging capabilities [1].

The radiation images (i.e. intensity histograms over the angular space around the detector, see Figure 3) are hereby calculated via double scatter events and then displayed on computer screens for the user to interpret. Mixed-reality (MR) technologies on the verge of wide scale commercial availability. MR refers to the continuum of devices and experiences between Augmented reality (AR), with virtual objects being displayed into the real space, and Virtual Reality (VR), a fully virtual experience. MR technologies can aid in the display and interpretation of complex data such as radiation images.

Herein, we present recent developments towards the visualization of radiation images from the H2DPI on the head-mounted Microsoft HoloLens 2 smart glasses device. Instead of needing to interpret the image on a screen and translate the information to the real space, the user is shown the relevant information directly a holographic visual impression. The long term goal is to develop an intuitive tool that allows for fast and reliable radiation source localization in 3D, as illustrated in Figure 1.

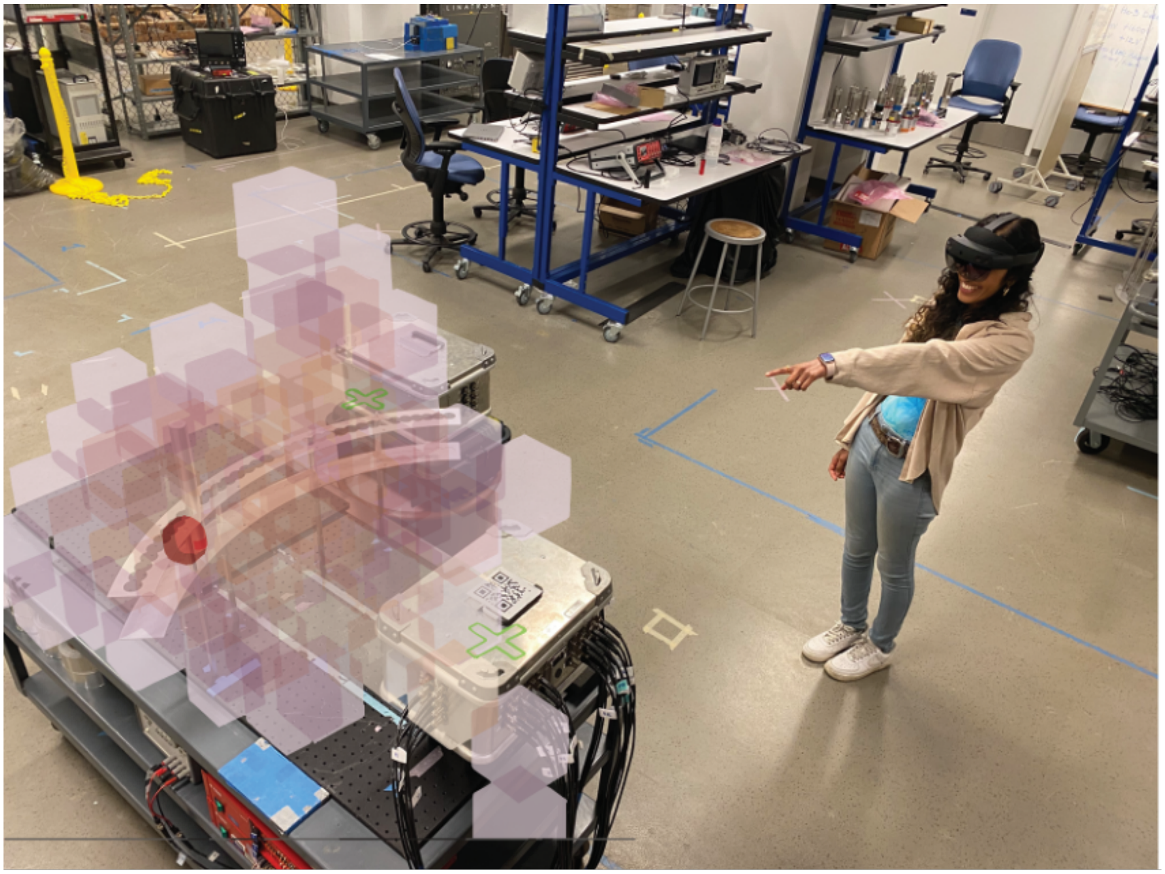

Figure 1. Depiction of the concept of 3D source localization using a mixed reality smart glass device and two radiation imaging devices. The user is wearing a head-mounted device (Microsoft HoloLens2) and is shown the information about radiation field intensity directly as a visual impression via holographic overlay projection. The intensity map could also be accompanied by more complex additional information: Energy spectra of neutrons and gamma rays, best-estimate predictions of source locations, or warning signs.

TECHNICAL APPROACH

The Handheld Dual Particle Imager (H2DPI) was developed at the University of Michigan [1]. Its most recent iteration consists of an array of 12 organic glass scintillators and 8 $CeBr_3$ crystals [2] (see Figure 2). The radiation images for gamma rays or neutrons are calculated via kinetic reconstruction of the incidence cone of double scatter events, and then overlapping many of these cones in a process called back-projection [2]. As shown in Figure 3, we first use pulse shape discrimination algorithms to distinguish neutron from gamma ray events. Then, the the neutron and/or gamma ray images are calculated. The resulting back-projection image is a measure of intensities in the spherical space around the detector, with the highest intensity being in the angular direction where most radiation is being detected from.

Figure 2. Picture of the Microsoft HoloLens 2 set on top of the H2DPI detector system. The HoloLens is a stand-alone battery powered computer system that can project holograms into a user's field of view. The holographic objects can be interacted with, and the physical world may impact holographs - this is also referred to as a mixed reality environment [3].

As the device to project mixed reality information to a user we use the Microsoft HoloLens 2 (see Figures 1 and 2). It is a head-mounted, battery powered, smart glass device that can show the user holographic objects in 3D. It houses several depth sensors in order to continuously construct a spatial mesh of its surroundings. Then, via wave-guide and lasers, the hologram is presented to the user's eye.

For this work, a custom set of programs were written that handle H2DPI raw pulse signal processing [2], image calculation, spatial localization of detector and user, and finally the image projection onto the spatial mesh. The details of the algorithm can be found in [4].

PRELIMINARY RESULTS

As an example of how the system works, we set a 0.85 mCi ^{252}Cf source in front of the H2DPI at around 50 cm distance. A user then donned the HoloLens and stood behind the detector, facing the source. We display the user's point of view with and without mixed reality in Figure 4. The current implementation projects rays into the angular direction of highest intensity of the radiation image and intersects these with the spatial mesh. The rays hereby correctly point at the source location, and convey the location to the user directly as visual impression.

The prime novelty is the reduction in interpretation burden: The complex data from a radiation image is intuitively displayed. Even visitors with no prior training were able to localize a radiation source using this method. Qualitatively speaking, we observed also a large amount of users who enjoyed the novelty of the experience.

To quantify whether the intuitive display is indeed better for data comprehension, speed of information processing, and task success rate is part of future work. This will then allow us to

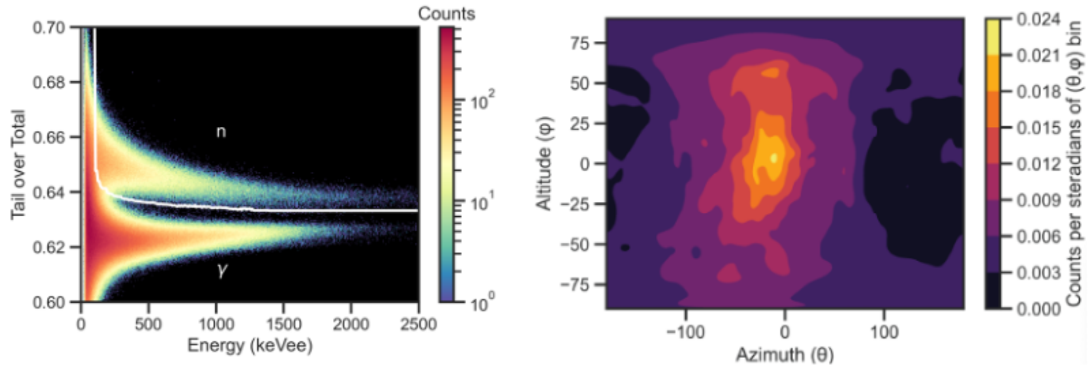

Figure 3. Left: Pulse shape discrimination plot for the organic scintillators in the H2DPI, plotting the pulse shape parameters over the measured light-output calibrated to keVee via a Cs-137 measurement. We specifically plot the tail over total integral ratio, with the tail integral beginning around 20 ns after the pulse peak. We can clearly discriminate two regions, one corresponding to gamma rays (fast decay, small tail) and fast neutrons (slow decay, large tail). The white line indicates the best fit line between the two regions determined via energy slice-wise fits of the pulse shape parameters with a two Gaussian model. **Right:** Using double scatter events of either gamma rays or fast neutrons, we can reconstruct the incident cone for each double scatter. By overlapping these incidence cones, a process called back projection, over the unit sphere around the detector, we can generate a radiation image. The resulting plot is intensity over spherical angular coordinates (Φ,Θ). The highest intensity angular direction is hereby indicative of a likely radiation source being located in said angular direction.

assess more specific scenarios, e.g., nuclear facility inspections and measure radiation exposure, inventory assessment time, and overall user comfort with and without the MR system.

CONCLUSIONS AND FUTURE WORK

Mixed reality technologies are at the verge of wide scale availability and can aid in the visualization and interpretation of complex data. Radiation imaging systems, such as the H2DPI, can be used to locate neutron and gamma ray sources in space and could provide relevant information in nuclear facility inspection or nuclear material inventory accounting scenarios. In this work we discussed the implementation of a mixed reality visualization method of radiation images produced by the H2DPI onto the head-mounted smart glass device HoloLens 2. We identified two key aspects of improvement: I) Interpretation burden reduction of complex radiation imaging data. Trained individuals may now be able to more confidently conduct a given inspection task. Conversely, untrained individuals could be enabled to perform source localization tasks - which could be relevant in emergency scenarios with limited access to trained personnel. II) Increase in the speed of information to the user, thereby reducing exposure times and received doses. Future work includes true 3D source localization using multiple (mobile) detectors as well as quantitative research into the benefits of using mixed reality visualization.

Figure 4. Left: Screenshot from the HoloLens showing the user's field of view without any holograms. The H2DPI is in view in front of the user, with a ^{252}Cf source set in front of the system. **Right:** Screenshot from the HoloLens showing the user's field of view with the mixed reality application running. The user is shown the intersection of the radiation image with the 3D mesh of the surrounding space via colored rays. In this case, the rays point towards the ^{252}Cf source, i.e. the correct incidence direction of radiation has been shown to the user.

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