Augmented Reality for Radiation Dose Awareness in the Catheterization Lab

Molly Flexman
Philips Research North America
2 Canal Park
Cambridge, Massachusetts 02141
molly.flexman@philips.com

Ashish Panse
Philips Research North America
2 Canal Park
Cambridge, Massachusetts 02141
ashish.panse@philips.com

Benoit Mory
Philips Research North America
2 Canal Park
Cambridge, Massachusetts 02141
benoit.mory@philips.com

Christopher Martel
Philips Research North America
2 Canal Park
Cambridge, Massachusetts 02141
chris.martel_1@philips.com

Atul Gupta, MD
Philips - Image Guided Therapy
3000 Minuteman Rd, Mailstop 4304
Andover, Massachusetts 01810
atul.gupta@philips.com

ABSTRACT

There is a growing awareness of the effects of radiation exposure to the patient and staff during minimally-invasive x-ray guided interventions. Augmented reality can provide real-time visualization of radiation dose during the procedure with relevant information displayed in the appropriate context.

CCS CONCEPTS

• **Human-centered computing → Mixed / augmented reality**; **Interface design prototyping**;

KEYWORDS

Augmented reality, medical interventions, catheterization lab, radiation dose

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1 INTRODUCTION AND MOTIVATION

There is an increasing trend towards minimally invasive procedures that use image guidance to navigate tools and deliver therapy within the body. Instead of having a direct view of the anatomy and tools, the clinician often relies on interventional x-ray, an imaging modality that uses ionizing radiation. Not only does ionizing radiation bring a risk to the patient, but also to the personnel who work daily in the catheterization lab (cathlab). There are early studies showing increased incidence of cataracts and left-side brain tumors to interventionalists who work in the cathlab every day [Bitarafan Rajabi et al. 2015; Roguin et al. 2013].

X-ray exposure is minimized by use of the "as low as reasonably achievable"(ALARA) principle. Numerous approaches and technologies exist to reduce radiation exposure to both the patient and personnel in the room. For example, protective equipment such as lead aprons, glasses, and shielding as well as lowering the detector and avoiding steep beam angles can reduce personnel exposure. Increasing the table height, varying the beam angle, and decreasing the frame rate are techniques to reduce dose to the patient.

The ALARA technique is most effective when personnel in the room have awareness of their dose. The instantaneous dose at each point in the room is constantly changing during the procedure based on the position of the x-ray source and detector, the imaging protocol, and the position of other objects in the room. The radiation dose is not uniformly distributed in the room. Knowledge of the dose distribution is important in reducing the dose to the personnel. Real-time dose monitoring solutions currently exist such as DoseAware (Philips, Best, NL) and RaySafe (Fluke Biomedical, Everett, WA). Personnel in the room wear a real-time dosimeter badge that wirelessly connects to a display with cumulative and instantaneous dose information for each user. Studies have shown that real-time dose awareness can lead to workflow changes that reduce radiation dose to both the patient and staff [Baumgartner et al. 2016]. Even a small increase in the distance between the personnel and the x-ray tube reduces their radiation exposure by a factor of the square of the distance. If the staff are aware of their instantaneous exposure during the procedure, they can work towards reducing their radiation exposure. There is a lot of information including patient images, patient statistics, hemodynamics, patient monitors that compete for screen space in the room. As a result, dose information is typically communicated to personnel via a small screen that cannot always be seen by everyone in the room and may not be noticed by the x-ray operator. Hence there is a strong motivation to have this information easily visible to all personnel in the room.

2 TECHNICAL APPROACH

Recent advances in augmented reality, and specifically in head-mounted displays for mixed reality, have opened up new opportunities to visualize information in the medical environment. There are multiple groups looking at how to bring augmented reality into

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the operating room with a strong focus on training and simulation. Our work brings augmented reality directly into procedure by demonstrating a method for creating dose awareness with novel real-time visualization.

Our approach is to use augmented reality to display information in context as opposed to relying on additional physical screens in the room. Every staff member wears a real-time dose monitor dose data is relayed wirelessly to a central computer. We embed a unique marker into each badge that is tracked by the HoloLens. To communicate staff dose, each staff member in the room has a dose avatar that represents their cumulative and instantaneous dose. For example, a sphere that hovers next to the person and communicates dose through its color and size. The dose data corresponding to the detected monitor, relayed from the central computer, is used to calculate the color and size of the dose avatar which is placed next to the person wearing the badge.

There are ongoing efforts to map real-time skin dose for the patient during interventional fluoroscopy procedures [Johnson et al. 2011]. Instead of placing these maps as an additional screen in the room, they can be visualized directly as an overlay on the patient. With current technology, the registration of the patient and the dose map will have to be carried out using markers detected by the HoloLens. The accuracy with this method is sufficient to display the dose map on the patient as the resolution of the dose map is quite low.

3 IMPLEMENTATION AND FUTURE WORK

We implement the functionality using Unity for the Microsoft Hololens Development Kit. Standard real-time dose badges are enhanced with a user-specific marker that is detected with Vuforia by PTC to identify the user within the view. A holographic sphere was placed at a specific offset position based on the detected marker position. The sphere modulates size to holographically depict the staff memberâĂŹs unique real-time dose, and progressively changes color according to a predefined color map that corresponds to the cumulative dose.

We have demonstrated a wearable augmented reality concept that removes barriers that exist due to the current forms of visualization and interaction present in the cathlab. This allows for the contextual display of information to raise awareness of dose during interventional procedures.

At the time of submission, we have shown this dose awareness application to 20+ clinicians to get their feedback. The following table shows the general comments about the feasibility of using an augmented reality headset in the cathlab.

Future work will also explore how new techniques for visualization of dose can translate into improvements in workflow and reduced dose to the patient and staff.

These concepts can also be applied more broadly to other applications where it is important to have real-time awareness of radiation exposure. For example, in radiation therapy, nuclear reactor sites, and for people working with radioactive isotopes.

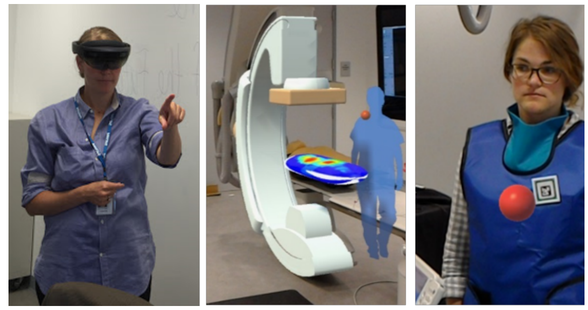

Figure 1: Images acquired using the HoloLens showing a dose map overlay for the patient (center) and a dose avatar hologram (red sphere) for a staff member working in the room.

Table 1: Summary of comments from clinicians about the HoloLens in cathlab environment

HoloLens property	Remarks
Weight	Lighter headset and balanced weight distribution required
Tethered computing unit	Can be tethered to a light computing unit on the body. Strong preference against tethering to a stand-alone computer
Sunglass effect	Desire for clear glass to view physical screens with high image-quality. Prefer no barrier between their eyes and the patient and other staff members.
Field of view	Bigger field of view required
Sterility	The glasses do not need to be sterile.However, to preserve sterility they cannot be touched during the procedure.
Lead glass	Integrate lead glass for radiation protection.

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