Visualization of Scattered X-ray Using Mixed Reality

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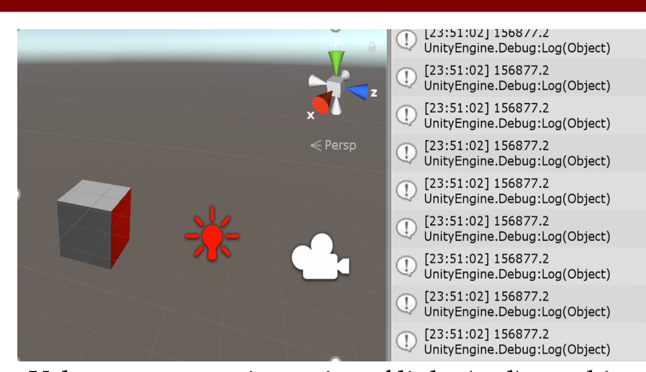
INTRODUCTION

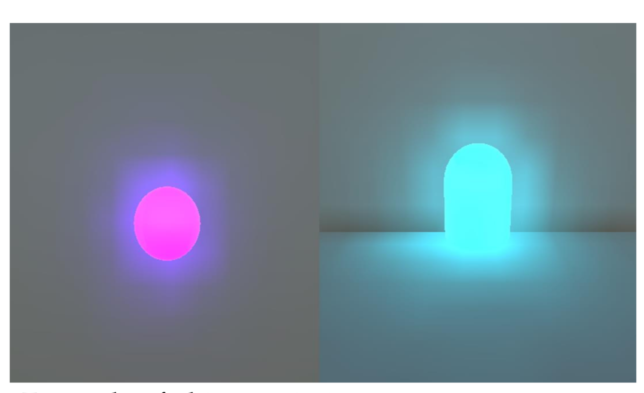
- X-ray imaging is widely used in surgical and interventional procedures. Currently, there are few ways to measure effective dose (ED) of radiation for patients and staff. Existing methods are often un-informative and ineffective at reducing ED.
- Dosimeters measure ED over a period but lack real-time measurements and feedback. Principles such as ALARA (As Low As Reasonably Achievable) are helpful, but unspecific and sometimes forgotten.
- New methods of visualization are necessary because staff ED values can vary as much as 40 times depending on location and use of proper equipment.
- **GOAL: Use mixed reality on the Hololens to effectively visualize scattered x-ray radiation as a safety training and education tool.**

METHODS

- I explored ways x-rays can be simulated using various lighting properties and Unity's native physics engine.
- Two best options emerged: (1) treat the object itself as the source of radiation (emission properties), or (2) simulating x-ray behavior similar to Monte Carlo method (particle systems).

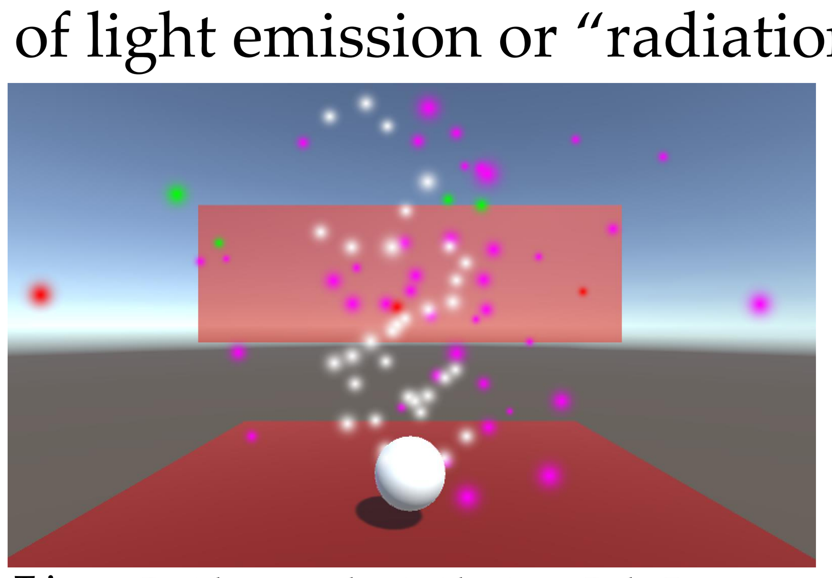


Values represent intensity of light (red) on object

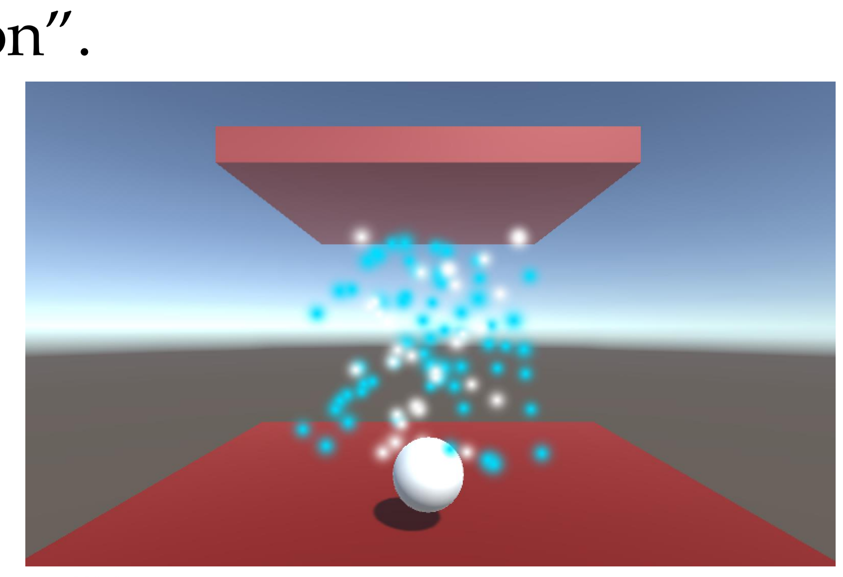


Example of object emission

Emission Properties are useful for generating heat map-like visualizations of scattered radiation. Using lighting properties, I created a method for measuring the intensity of light on a given object to dictate strength of light emission or "radiation".

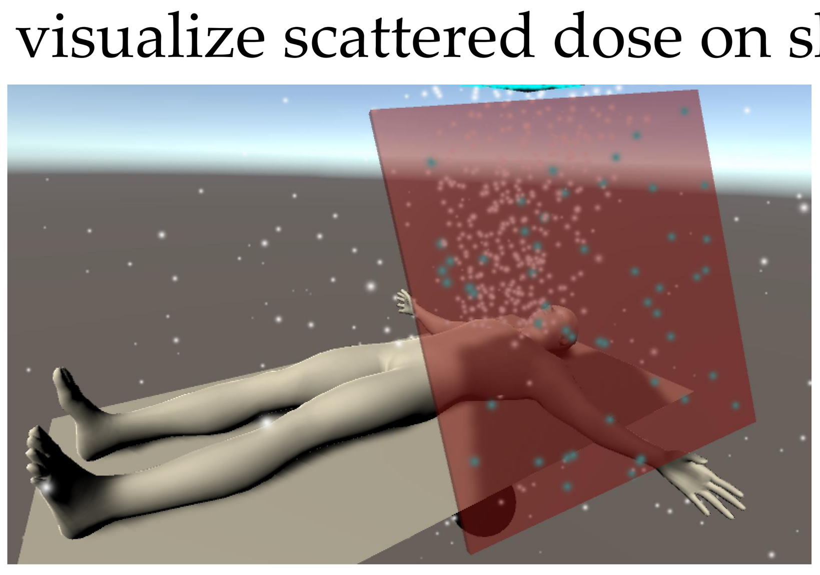


Triggers Particles react when inside trigger. Red = Enter, Pink = Inside, Green = Exit, White = Unaffected

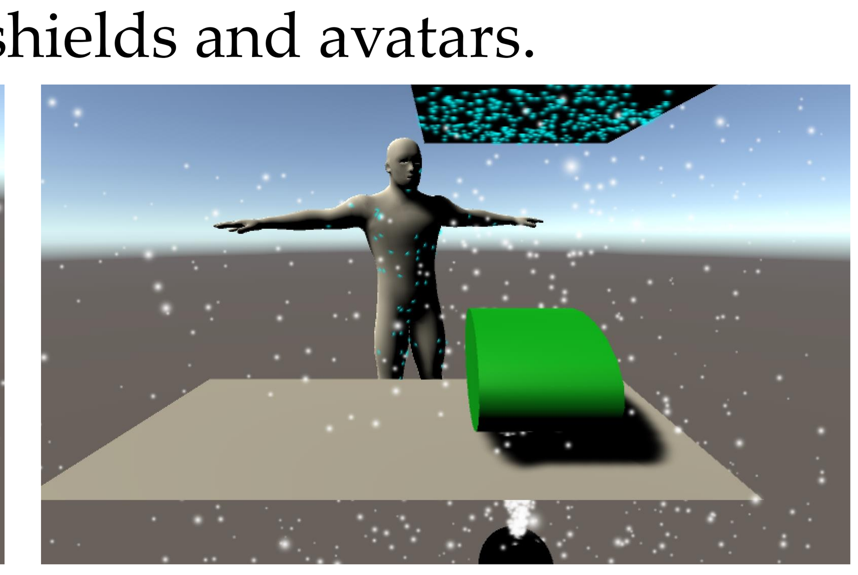


Colliders Particles turn blue when in contact with colliders

Particle Systems are more effective because of the custom particle behavior. Using scripts, colliders, and triggers, I simulated x-ray behavior by creating random absorption and (isotropic) scattering events when within a medium. Particle collision properties are used to simulate image detection on the detector as well as visualize scattered dose on shields and avatars.

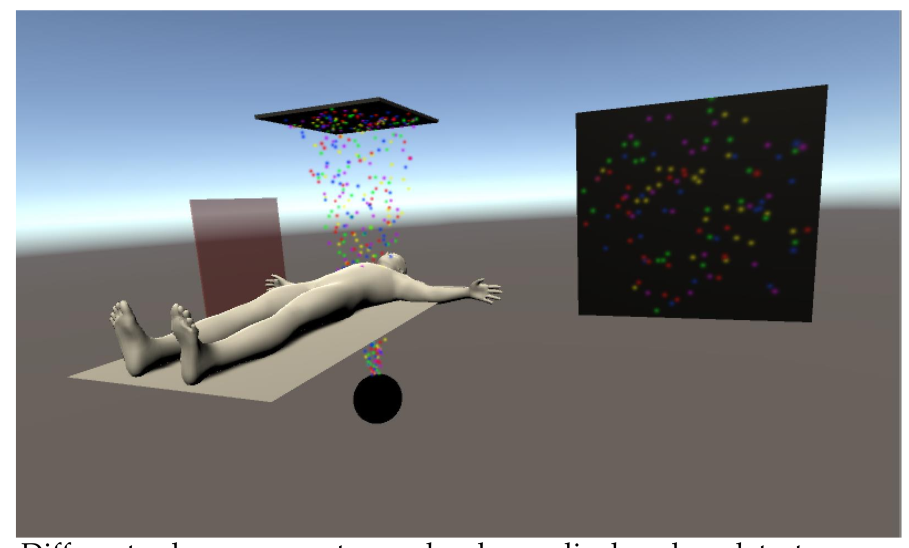


Blue particle represents blocked x-rays by lead shield (red plate)

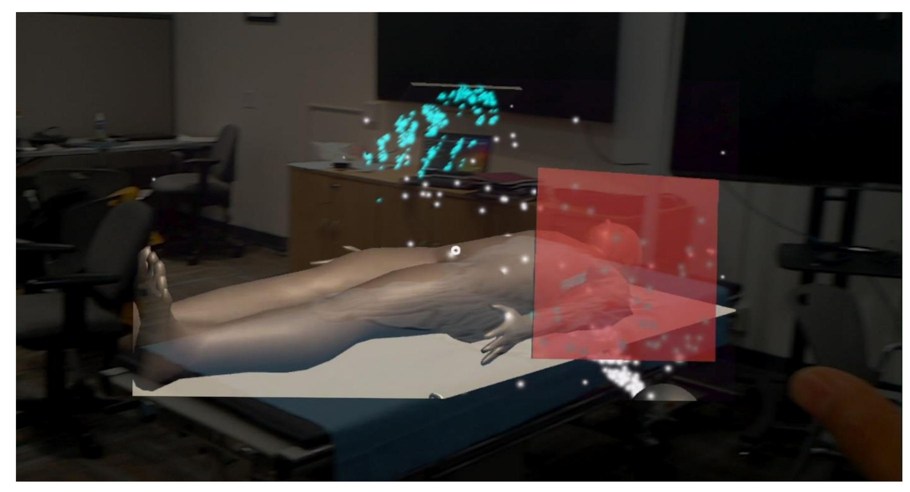


Avatar showing absorbed effective dose (blue particles).

RESULTS & DISCUSSION



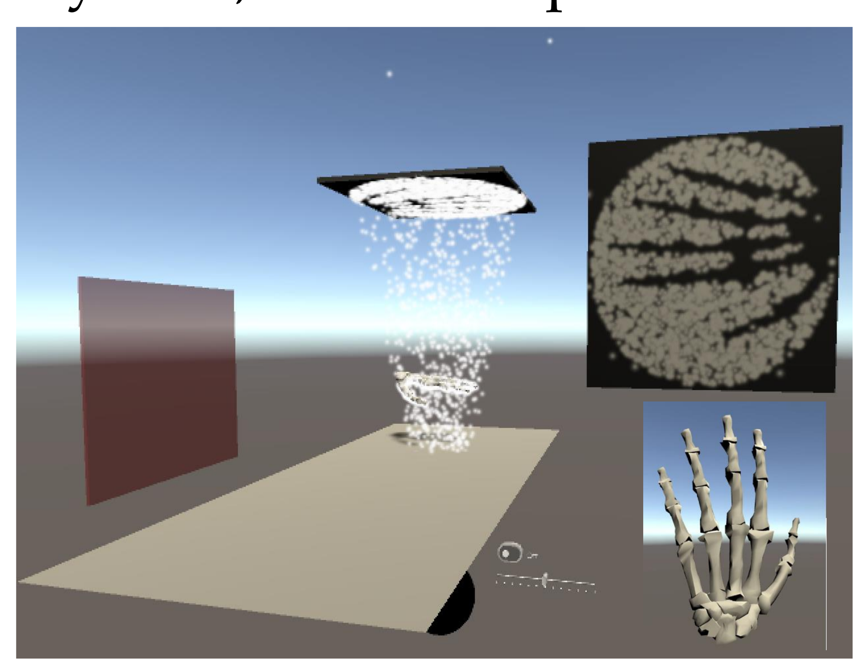
Different colors represent x-ray hardness, displayed on detector screen.



X-ray model rotated at 60° superimposed onto physical table.

- The final project is a primitive model of a C-arm x-ray system. The sphere represents a source of x-rays that are either absorbed or scattered within the "patient" or settles on the detector to create an image. This image can be seen on a plane beside the model.

- Other features include a moveable lead shield and user avatar, multiple colors for x-ray energy, rotating x-ray system, and multiple scanned objects.



X-ray simulation of hand skeleton. Image is displayed on detector screen.

Moveable avatar capable of absorbing dose shown in real world. Lead shield also protects user from dose.

- Multiple options make particle systems a powerful visual aid for visualizing and understanding scattered radiation behavior. Ability to refine particle behavior and add numerous shields, avatars, and materials will allow more accurate representations of interventional suites, ideally with which holograms can be overlaid.
- Main limitations come from capability of hardware processing power. Frame rate drops significantly around 10,000 particles. Future work includes more realistic x-ray behavior, including objects with multiple materials, material- and energy-specific interaction properties, and anisotropic scattering.

CONCLUSION

- Mixed reality is a powerful tool that allows users to superimpose holograms onto their physical world. Using mixed reality to visualize scattered radiation is a safe and compelling way to learn about radiation behavior to increase safety.
- Ideally this tool could be used as an intraoperative tool to reduce effective dose to patient and staff but also doubles as an educational tool to teach radiation safety.
- This is only an early implementation of Unity and its physics engine. Initial results are promising, and future work can lead to immense potential for this technology.

References: Hein Heidbuchel, Fred H.M. Wittkampf, Eliseo Vano, Sabine Ernst, Richard Schilling, Eugenio Picano, Lluis Mont, ESC Scientific Document Group, Practical ways to reduce radiation dose for patients and staff during device implantations and electrophysiological procedures, EP Europace, Volume 16, Issue 7, July 2014, Pages 946–964, https://doi.org/10.1093/europace/eut409