3D Compton Imaging of Distributed Sources Around the Chernobyl NPP

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Introduction

The **detection, characterization, localization, and mapping** of **gamma-ray source distributions** in **real-world environments** is useful for many applications including **safeguards, emergency response, and nuclear contamination remediation**. Traditionally, radiation mapping is performed with hand monitoring or a series of 2D static measurements, but portable detection systems with contextual sensors have been developed which can allow for free-moving 3D gamma-ray imaging in a method called scene data fusion (SDF) [1].

3D Compton Imaging

Compton imaging is a gamma-ray imaging modality based on Compton scattering

- Double interaction events - a Compton scatter followed by a photoelectric absorption
- To localize 137Cs, use events that deposit 662 keV in the detector across its two interactions.
- Compton cones are defined by a scatter axis given interaction positions and cone opening angle using Compton kinematics.

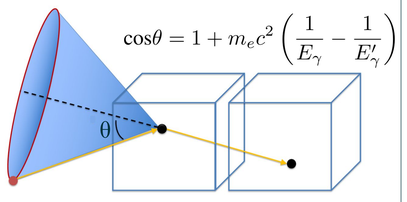

Fig. 1: Compton cone generated from double interaction events

2D Compton	3D Compton	Free-moving 3D Compton
• 3D positions of 1st two interactions • Energy deposited in each interaction	• Everything for 2D Compton • Position and orientation at each measurement to properly rotate and translate Compton cones	• Everything from 3D Compton • Real time solution of position and orientation during each gamma-ray event

Polaris-LAMP and Scene Data Fusion

Polaris-LAMP is the commercially available Polaris-H quad detector fitted with LBNL's LAMP package

- **Polaris-H:** pixelated CdZnTe detector developed as a 2D static imager [2].
- **LAMP package**: onboard computer, LiDAR unit, visual camera, inertial measurement unit (IMU), and a GPS module [3]
- **Simultaneous Localization and Mapping (SLAM):** continuously updates a map of surroundings and estimates pose as the detector moves through the scene [4].

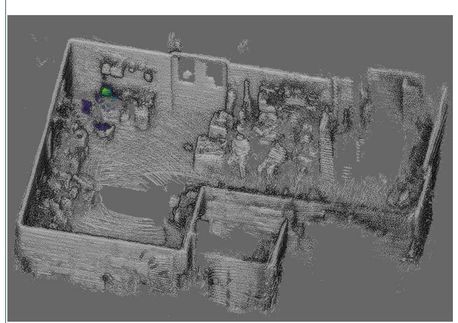

Fig. 3: SDF demonstrated with a ^{137}Cs point source in a laboratory setting. Reconstruction on 662 +/- 10 keV gammas with 546 Compton cones

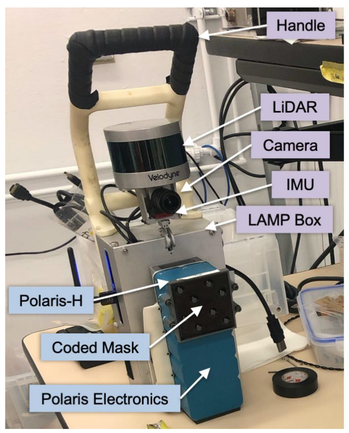

Fig. 2: Polaris-LAMP detector system

Scene Data Fusion (SDF) is a method of equipping portable radiation detection systems with contextual sensors to allow free-moving 3D gamma-ray imaging

- 3D image reconstruction is constrained to intersections of Compton cones with surfaces present in the scene

Chernobyl Measurement

Significant contamination remains across the Chernobyl Nuclear Power Plant (CNPP) exclusion zone despite ongoing remediation efforts. The primary contaminant is Cs-137, with a gamma-ray energy of 662 keV.

To demonstrate its effectiveness in **mapping distributed radiation source environments**, Polaris-LAMP was brought to:

- Chernobyl Nuclear Power Plant
- Pripyat, the abandoned working town for the plant.
- Slavutych, the nearby town constructed for the CNPP remediation effort.

Pripyat Town Center

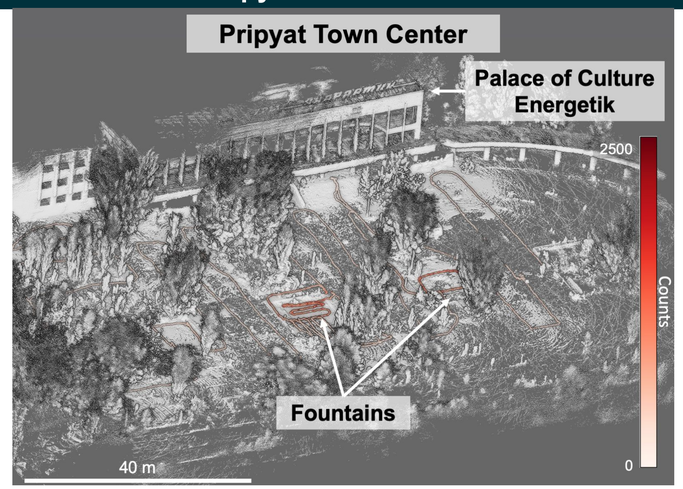

Fig. 4: A 20 minute measurement in the Pripyat town center. This scene consists of abandoned buildings and several fountains and trees. The walking path of the detector during the measurement is colorized by gross counts from the detector.

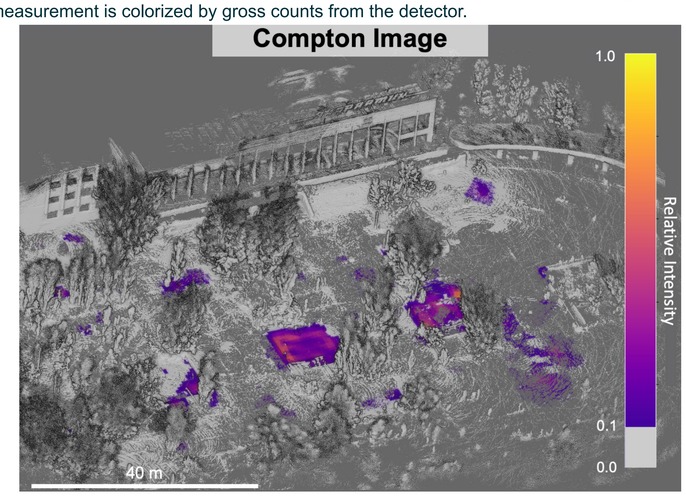

Fig. 5: Compton reconstruction on the scene, colorized to show weight on a min-max normalized scale. Colorization is suppressed for the bottom 10% of weight. The fountain wells collected contaminated rain and groundwater following the CNPP accident, resulting in high weight

Pripyat Amusement Park

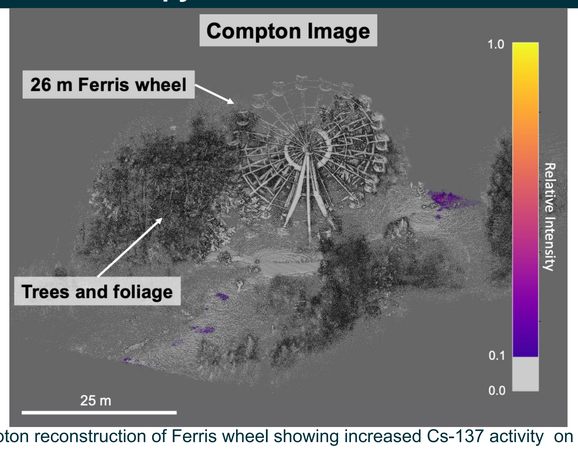

Fig. 6: Compton reconstruction of Ferris wheel showing increased Cs-137 activity on the ground near the Ferris wheel

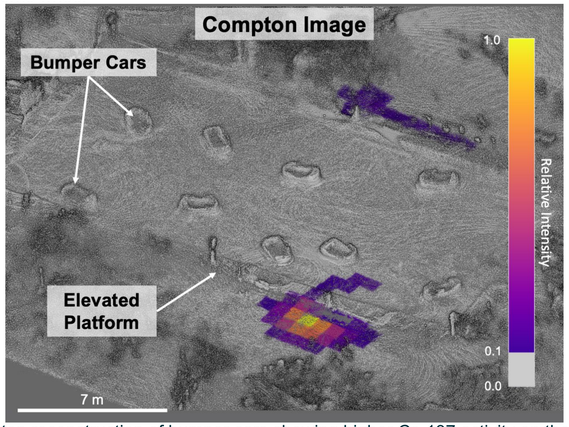

Fig. 7: Compton reconstruction of bumper cars showing higher Cs-137 activity on the sides of the elevated platform, consistent with washout of contamination from rain

Summary

- The LAMP package can capture and reconstruct relevant scene data, including the iconic Pripyat ferris wheel.
- 3D Compton SDF can generate contextual radiation maps in areas around the Chernobyl Nuclear Power Plant.
- These techniques could be extended to construct dose-rate maps of the Pripyat area, providing important information in assessing and monitoring radiological contamination.

References

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