

Identifying Radiation Sources in BIM with Gamma-ray Imaging

Hyong Chol Kim*, Jae Hee Roh, Moonjoo Gil, Young Jin Lee
NSE Technology Inc., 5F Convergence Technology Research Commercialization Center
218 Gajeong-ro, Yuseong-gu, Daejeon, 34129, Korea
*Corresponding author: hckim@nsetec.com

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1. Introduction

3D modeling is commonly used to visualize the decommissioning process of nuclear facilities [1] and also to assess doses for ALARA planning [2], and BIM (Building Information Modeling)-based frameworks are often used to manage the decommissioning process [3]. Once a BIM is built for a nuclear facility, its 3D model and the associated property data can be used to establish the physical relationship between the radioactive sources and the dose rates in the radiation field. The waste inventory by radioactivity level can be assessed easily utilizing the material properties of the objects contained in the BIM.

Recent studies have shown that 3D model-based methods can be utilized to determine the activities of radiation sources using the dose rates measured in the field [4-5]. However, locating radiation sources in the nuclear facility environment is challenging, requiring extensive radiation surveys with numerous readings throughout the work area. In practice, site technicians' knowledge of the location of sources or hotspots within the surveyed area should be utilized [2]. However, implementing a BIM with complete information, including the radioactivity of source objects, necessitates a need for additional technical means beyond these methods, as accurately locating sources and identifying the corresponding objects within the nuclear facility environment is crucial.

This study presents a method to identify the radiation sources and their corresponding objects in the BIM using a gamma-ray imager.

2. Methods and Results

2.1 Establishment of the BIM

The 3D BIM model of a nuclear facility is generated using 3D modeling tools like Revit, based on the facility's 2D drawings and supplemented with any deviations detected through comparison to laser scanning point cloud data. A developed software tool called BIMRAD was used to represent the objects in the 3D space and link the material property data to the objects.

A pilot BIM has been established for the RCP test facility [6]. Fig. 1 shows the overall view of the established BIM with the outer walls removed for better visibility.

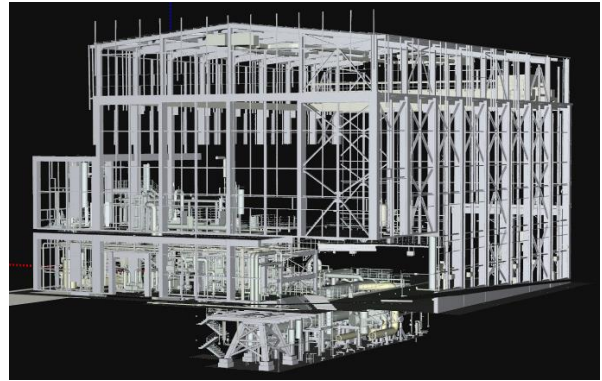


Fig. 1. Overall view of the BIM of the test facility.

2.2 Use of the Gamma-ray Imager

A gamma-ray imager [7] was used to locate the radioactive sources. However, since the facility does not handle radioactive-contaminated equipment, test sources below the level of regulatory exemption were attached to equipment surfaces in the basement of the facility. Fig. 2 shows the camera image obtained by the gamma-ray imager, indicating the identified source locations and isotopes.



Fig. 2. Camera image of the identified source locations and isotopes.

The gamma-ray imager also provides the camera image overlaid with the Compton image as shown in Fig. 3. The gamma image is aligned by software to match the field of view captured by the camera lens.

The gamma-ray imager, through a specialized function, provides two types of the Compton image data: one is the projection data that covers the forward solid angle of 2π , and the other is the spherical data that covers the whole solid angle of 4π from the detector.

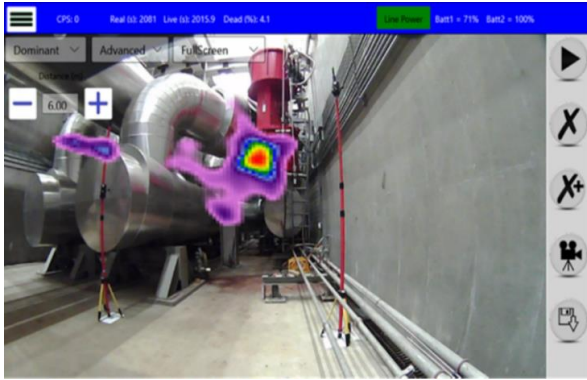


Fig. 3. Camera image with the Compton image of the sources.

Fig. 4 shows the surface type chart of the projection data in a 201×201 grid, corresponding to the Compton image of Fig. 3. While the overall contour pattern resembles Fig. 3, slight differences arise due to the alignment of the gamma image with the camera image.



Fig. 4. Surface type chart of the projection data.

Fig. 5 shows the surface type chart of the spherical data in a 180×180 grid. Unlike the projection data, directly visualizing the 4π data is challenging because it was recorded in a two-dimensional format. Here, the row direction represents the polar angle (θ) and the column direction represents the azimuthal angle (φ) when the detector faces the polar direction.

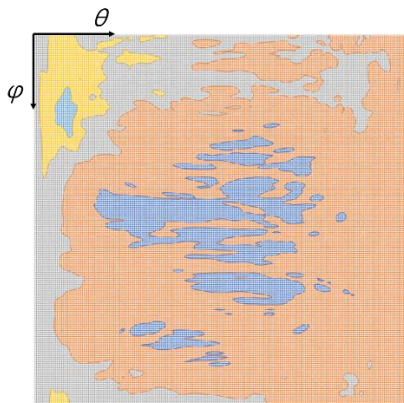


Fig. 5. Surface type chart of the spherical data.

2.3 Source Identification in the BIM space

In BIMRAD, the local coordinate system of the detector is transformed into the global coordinate system of the BIM space. This allows displaying the 4π Compton data such as Fig. 5 on the BIM, provided the detector's position and direction are known in the global coordinate system.

The coordinate of the detector position was determined using an indoor navigation system [8]. This system consists of a network of stationary ultrasonic beacons interconnected via radio, a mobile beacon attached to the detector, and a modem that allows connection to a computer.

The system forms its own coordinate system by setting the origin at the first stationary beacon's coordinate and the direction of the second stationary beacon as the x-direction. The mobile beacon's location is then calculated using the trilateration algorithm, based on the time-of-flight delay of the ultrasonic pulses between stationary and mobile beacons.

If the first stationary beacon is located at the designated reference position of the BIM and the x-direction is aligned with the facility's walls and floor, the mobile beacon's location in the navigation system can be easily converted to the BIM space coordinate.

Fig. 6 displays the BIM image with the spherical Compton data from Fig. 5, presented in a field of view similar to Fig. 3. The radiation contours in both figures show a high degree of similarity.

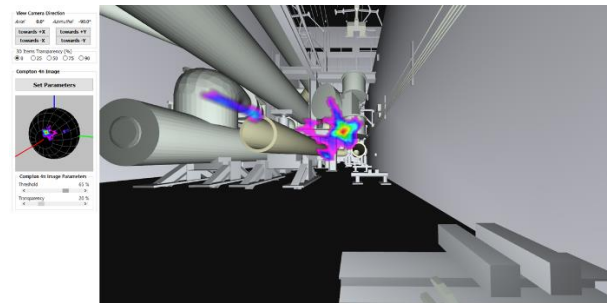


Fig. 6. BIM image with the spherical Compton data displayed.

This BIM view allows us to directly locate and assign properties to radioactive source objects within the model. A key advantage of using 4π spherical Compton data on the BIM is its ability to identify both sources in front of and behind the detector, unlike conventional methods. Once all the sources are identified, BIMRAD software can then determine the radioactivity of each identified source using dose rate measurements taken in the field [4-5].

3. Conclusions

A 3D model-based software, BIMRAD, has been enhanced to identify radioactive sources within BIMs.

This improvement leverages data collected by a gamma-ray imager, providing a complete 4π picture of

Compton data. This data can be directly imported into BIMRAD, allowing for direct visualization and analysis within the BIM environment, streamlining the identification of radioactive sources. Notably, the 4π Compton data enables the detection of sources in all directions, including those behind the detector.

An indoor navigation system was used alongside the gamma-ray imager to determine the detector's position.

The enhanced source identification feature is expected to integrate seamlessly with the existing method of determining source activity using dose rate measurements.

The functionality of the enhanced BIMRAD feature was demonstrated through a test using test sources placed within a facility.

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