GammaModeler™, 3-D Gamma Ray Imaging Technology

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ABSTRACT

The AIL GammaModeler™ 3-D visual and gamma-ray imaging system was successfully demonstrated at the DOE Hanford Site 221-U facility as part of the Canyon Disposition Initiative (CDI). Measurements were taken of canyon equipment from several viewing directions using the GammaModeler™ camera. The combined radiation and visual data were rendered as 3-D drawings that allow the user to view the representation from any angle. The gamma-ray sources are color coded to represent the radiation intensities. The known coordinates and intensities of the sources allow calculations of dose estimates to be performed for any position relative to the canyon equipment. These positional and intensity data allow better dose mapping in the canyon area that should improve planning decision-making with respects to the goals of the CDI.

INTRODUCTION

The Canyon Disposition Initiative (CDI) is a jointly funded project at the Department of Energy's Hanford site, which is located in the southeastern Washington State. Participating Environmental Management (EM) offices include the Office of Waste Management (EM-30), the Office of Environmental Restoration (EM-40), The Office of Science and Technology (EM-50), and the Office of Nuclear Material and Facility Stabilization (EM-60). This partnership is evaluating the feasibility of utilizing the five massive fuel-reprocessing facilities (canyons) in the 200 Areas as waste repositories, among other disposition alternatives. The 221-U Facility is the "pilot" project for the CDI. As part of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Remedial Investigation/Feasibility Study, extensive characterization of the 221-U Facility is underway. The characterization data collected, measured, derived, etc. are required to support a Performance Assessment , which will lead to a Record of Decision.

OBJECTIVE

The 3-D GammaModeler™ visual and gamma ray imaging system was developed by AIL Systems Inc. to remotely survey large areas for gamma-ray emissions and display the results as combined 3-D representations of the radiation sources and the equipment. The objective of the demonstration of the 3-D GammaModeler™ system at the

Department of Energy Hanford site 221- U Facility is to identify potentially beneficial technologies for the Canyon Disposition Initiative (CDI). During the demonstration, the GammaModeler™ system was used to survey a portion of the facility and provide visual and radiation measurements of contaminated equipment located within the facility. The system provides information on source locations interior to the visual objects and provides a better estimate of the source intensities. The use of 3-D visual and gamma ray information supports improved planning decision-making, and aids in communications with regulators and stakeholders. The demonstration was performed from August 18 – August 26, 1999. Measurements were taken during four of those days.

PROJECT DESCRIPTION

The 3-D GammaModeler™ system consists of four modules: a sensor head, a portable PC compatible computer, a pan and tilt controller, and a 3-D workstation. The sensor head, shown in figure 1, incorporates a coded aperture gamma ray imaging detector, a high-resolution video camera, a laser range finder, and a pan and tilt assembly. For the demonstration the sensor head was wrapped in plastic to prevent contamination and mounted via a special adapter to the facilities crane hook. The PC and pan and tilt controllers were located in the crane cab for remote operation of the sensor head. By mounting the sensor head on the crane hook, the sensor head could be remotely positioned anywhere in the canyon and could point in any direction using the pan and tilt assembly. However, the tilt angles were restricted to +/- 73 degrees so looking straight down on an object was not possible. The video field of view (FOV) was 73^o horizontal by 55^o vertical and the gamma FOV was 25^o by 25^o degrees with an angular resolution of 1.3 degrees. The sensor head has a spectral range from ~100 keV to > 1.3 MeV with a sensitivity for ^{137}Cs of one microR dose with the highest sensitivity in the center of the FOV. The system is able to operate in both low level (< 15 microR/hr) and high level (>100 R/hr) radiation environments with no shielding required.

Figure 1. 3-D GammaModeler™ Sensor Head

AIL personnel operated the GammaModeler™ system and the crane operator positioned the sensor head near the objects to be surveyed for gamma radiation sources. A pseudocolor image of gamma ray emitting sources is displayed as a composite picture with the video picture of the scene. The gamma ray intensities above a detection threshold are automatically scaled to indicate the highest radiation level as red and the lowest level as blue. The video picture has a wider FOV than the gamma FOV so the boundaries of the gamma images are indicated in the composite picture by a rectangular box. Parallax corrections are applied in positioning the gamma ray image with respect to the video image so the gamma sources appear at the proper visual location. The exposure time required to obtain a gamma image is dependent upon several factors including gamma ray energy, the distance to the source, and the shape and distribution of the source. Additional images taken by the operator provide vector range to key references in the scene. These marker images are used to locate the position of the sensor head. The system software, *GammaSoft*™, produces a single file that contains all the images and the system measurement parameters. This file is copied to a disk for transfer to the 3-D workstation located outside the canyon area.

For those objects with detectable radiation, *GammaSoft*™ is used to generate files that are used by the *3-D processing* software in addition to the images in graphic format. The files used by the *3-D processing* software are marker files and the gamma ray count file for the gamma ray image. The marker files contain an ordered list of the range and direction to each reference point for a given sensor head location. For each sensor head location, the reference points are cross-referenced to reference points for other sensor head locations. From these data, the relative positions of the sensor head locations can be determined. If a reference point is on the object being surveyed, that position can be determined also. From the gamma radiation image data, location in the image corresponds to a direction from the gamma detector axis. For extended sources, line sources, etc., the 2-D image can be deconvolved into a series of point sources using our knowledge of the point-spread function for the detector. The locations in the image of the resulting point sources are the directions to the true locations for the sources. The deconvolution analysis also provides the intensity of the source at the sensor head. This intensity can be converted to a dose at the sensor head for the source. Similar to the reference points the sources seen in a 2-D view must be cross-referenced to the sources seen in another 2-D view. By knowing the sensor head positions, the pointing directions for the sensor head, the directions of the radiation sources for each view, and the cross-referencing of the sources, the 3-D location of the sources can be calculated along with their source strengths. The source strengths are calculated from each image in which the source is detected. If there is no differential attenuation between the views, then the calculated source strengths agree. If there is a difference, then the largest value for the source strength is reported. The results are stored to a file that can be used by *GammaCad*™ to merge these results with the visual representations in AUTOCAD.

RESULTS

A total of 20 objects were imaged during the demonstration period at the 221-U Facility. Seven of these objects had observable gamma radiation and measurements were taken at several viewing angles to support the 3-D rendering of the objects.

The high rad tank on Cell 35 was the first object imaged during the demonstration and was observed to have gamma emissions. This object was measured from four viewing directions. In addition to the four gamma images, a total of 27 marker images were obtained. The four gamma images are shown in figures 2 – 5. In figures 2,4,and 5, the source is observed to be an elongated source rather than a point source. The view from the side does not show the source strongly. This is probably due to some internal structure that attenuates the gamma radiation. The source seen in fig. 3 is treated as an ambiguous source that cannot be triangulated with other views. The gamma FOV for these figures is indicated by the rectangular outline within the figure. For sensor head position 1, the source is clearly seen to be near the bottom of the object. However, for sensor positions 3 and 4, the source is not near the bottom but does change location with the viewing angle.

Figure 2. Sensor Position 1

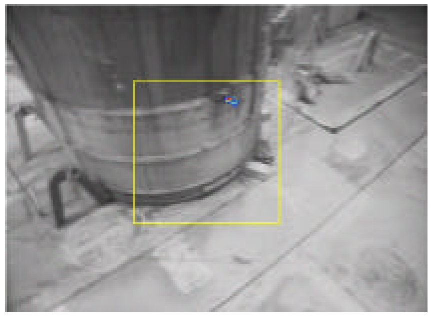

Figure 3. Sensor Position 2

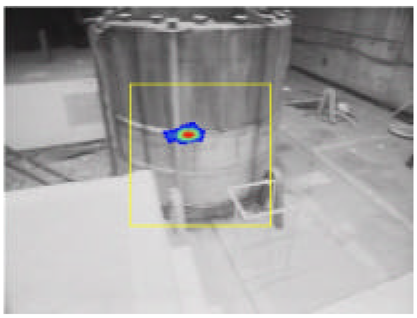

Figure 4. Sensor Position 3

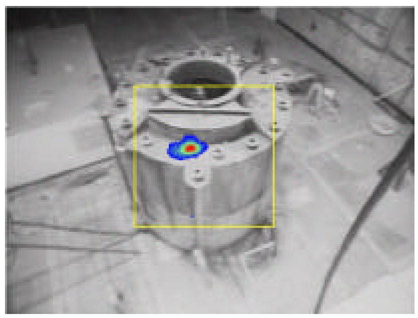

Figure 5. Sensor Position 4

In the coordinate system of the object, the y direction is along the canyon length, and the x direction is across the canyon. In figure 2 (sensor head position 1), the sensor is located in the positive y direction and in the negative x direction relative to the tank. Sensor positions 3 and 4 are behind the tank in the negative y direction. Sensor position 4 was taken from a higher elevation than sensor position 3 with the sensor head tilted down more to keep the tank in the FOV.

For each 2-D image, the extended source was deconvolved into five point sources. The direction from the sensor head to the source locations was determined and the intensity at the sensor head. Knowing the sensor head locations and the directions to the sources, the source positions are determined by the positions of closest approach for the source ray traces. Figure 6 shows a 3-D plot locating the sensor head locations (small labeled boxes), the direction ray traces from the sensor locations, the locations of closest approach, and the source position for each pair of ray traces. In this figure, the sensor head locations have been adjusted so that the coordinate (0,0,0) corresponds to the bottom center of the tank. The same program that generates this plot generates the file, which contains the source locations and the 30-cm dose values.

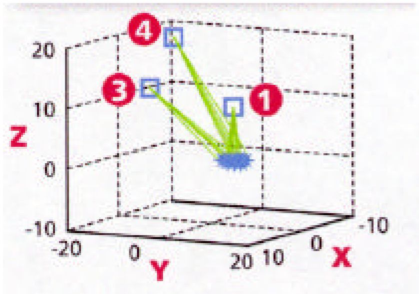

Figure 6. Calculated sensor positions, source positions

A 3-D representation of the object was generated using AUTOCAD. From the marker image data, it was determined that the tank diameter was 10 feet. The tank's center was positioned at x=0 and y=0. There the visual representation coordinate system is the same as that for the gamma radiation analysis. The tank was made transparent so that the sources located interior to the tank can be seen in the merged drawing. *GammaCad*[TM] is used to merge the gamma radiation data with the visual representation. *GammaCad*[TM] opens the AUTOCAD drawing of the visual object and the file containing the gamma radiation source information. The program creates color spheres for each of the point sources. The color of the spheres is related to the strength of the source. Red corresponds to those sources in the highest 1/3 intensity. Green corresponds to the middle third. Blue corresponds to the lowest third. Figures 7 and 8 show the merged 3-D visual and gamma radiation results as an AUTOCAD representation. AUTOCAD allows the object to be viewed from any direction. The two figures represent different rotations of the same object. Five colored spheres represent the extended source; their color relates to the 30-cm dose strength. The center sphere is red and corresponds to 810 mR/hr (the most intense source). In figure 7, the sphere on the right is blue representing 200mR/hr (within the lowest third strength). The other spheres are green and have values between 290 and 550 mR/hr.

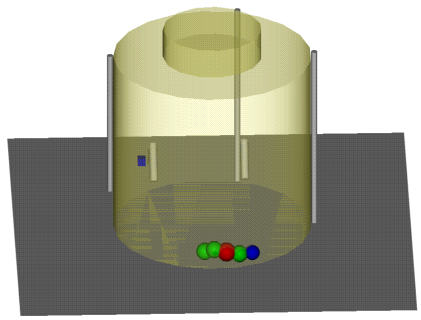

Figure 7. 3-D rendering of high rad tank.

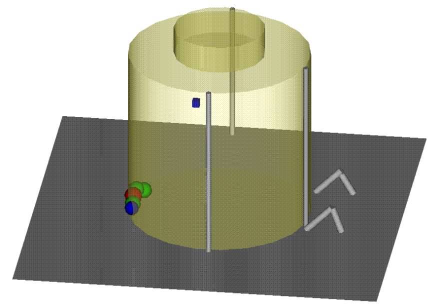

Figure 8. 3-D rendering of the high rad tank. Rotated approximately 90 degrees from the previous view.

A program called DOSE that can calculate the dose at any position in the coordinate system reads the file of the radiation sources. Figure 9 shows a screen capture of a dose calculation for the high rad tank. The program requests the file name and then the coordinates for the point where the dose is desired. The coordinates correspond to a location near the edge of the radiation exclusion zone. The calculated dose is 21 mR/hr. The calculation can be repeated for another location. Another program called MDOSE can calculate the dose resulting from multiple objects by combining files resulting from the analyses of additional objects and absolute canyon coordinates for each object.

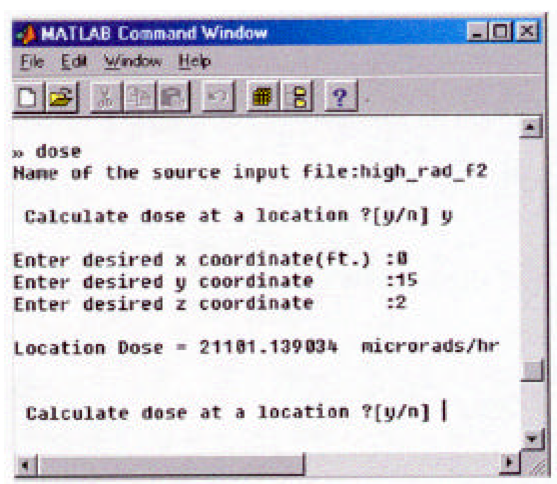

Figure 9. Typical dose calculation.

TECHNOLOGY APPLICABILITY

The applicability and benefits of AIL's 3-D GammaModeler^{TM} Gamma Ray Imaging technology at the U-Facility includes:

- Characterization with minimum exposure to personnel
- Rapid characterization via imaging of large areas from a safe standoff distance
- Characterization in a high radiation environment
- Characterization of radiation environment internal to the equipment
- Characterization that provides a visual electronic records
- 3-D localization of sources provides better estimates of radiation intensities, which leads to cost effective D&D planning and operation.
- Pan and Tilt capability allows measurements from new directions previously not available.