Radiological characterisation using radiation imaging and ground penetrating radar

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1 Introduction

Non-destructive characterisation of hidden (e.g. underground) radioactive waste is desirable. However, non-destructive techniques such as radiation imaging [1] are limited to visible wastes hence the need for combination with other non-destructive techniques. Ground penetrating radar (GPR) is a widely used reliable non-destructive technique for locating objects below the ground. Therefore, this work aims to augment 2D surface radiation images with complimentary information from GPR to enable 3D localisation of underground wastes.

2 Methodology

The study was carried out using a combination of MCNPX [2] and *gprMax* [3] simulations. The model used for the study is shown in Figure 1. It is a section of two underground pipes (radius = 5 cm) for transporting liquid radioactive waste. Both pipes are separated vertically and horizontally and are emitting radiation from points on their respective centres. These points could represent leaks from escaping liquid wastes or contaminated region due to activation of the steel by fission products in the liquid wastes. The MCNPX model consists of two steel cylindrical pipes (density = 7.82 g cm^{-3}) buried in dry sand (density = 1.7 g cm^{-3}). The contaminated points were modelled as Co-60 point sources which typically results from neutron activation of Cobalt in steel. In *gprMax*, the scenario was modelled as two perfect electrical conducting cylinders buried in dry sand (relative permittivity = 2.6).

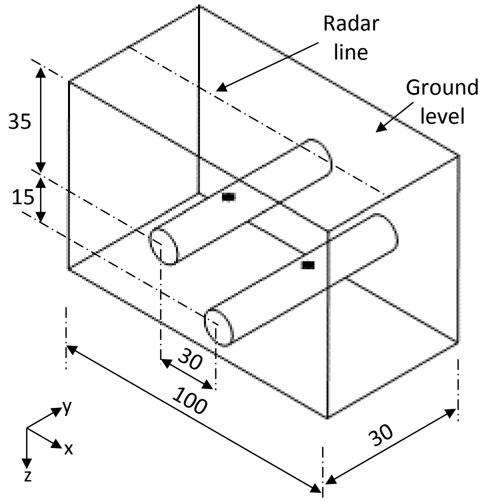

Figure 1: Model of buried pipes (in cm)

The radiation image was acquired by a lattice of 29 × 15 detectors placed 40 cm above the ground and centred at the x-y plane. Each lattice is a 2 cm × 2 cm cell consisting of a circular detector of radius = 0.5 cm surrounded by 0.5 cm thick tungsten collimator which is 10 cm long. Only 29 cells where place along the x-axis because these were enough to cover both pipes. The radar data was obtained by a transmitter-receiver pair at 256 locations along the radar line (Figure 1), which is centred at the y-axis. The transmitter was excited with a Gaussian wavelet centred at 1 GHz because of the shallow depth of the pipes.

3 Results and Discussions

The radiation image is shown in Figure 2a after resampling and smoothing with a 25 × 25 pixel Gaussian window [4]. The effect of dispersion of the gamma photons due to sand particles is apparent even with the application of the Gaussian window. Therefore, a more robust filtering that takes into account this dispersion effect will be required for improved imaging. Furthermore, the vertical separation between the two pipes is not observable in the radiation image because of lack of depth information. Figure 2b shows the radar image after background subtraction and match filtering [5]. This yield the required depth information as it shows the point where the GPR signals were reflected by the pipe surfaces.

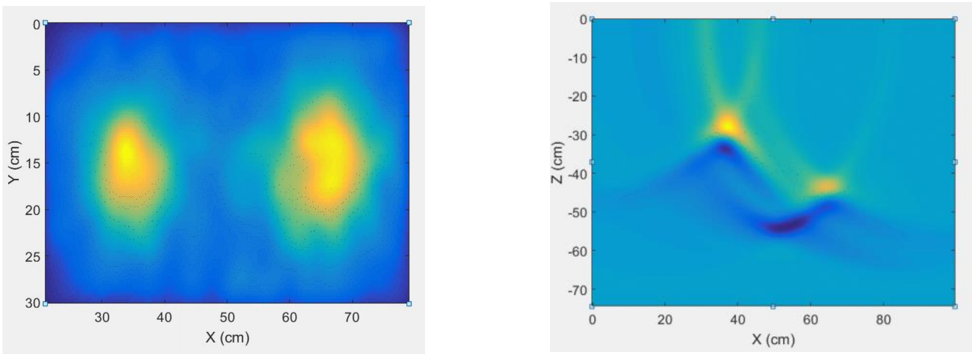

Figure 2. a) Radiation Image. b) Radar image (B-scan)

Using the depth information, the radiation image can be backprojected into the ground to yield a 3D localised radiation image as shown in Figure 3. This is a significant improvement compared to combining radiation imaging and LIDAR [6] which is limited to only visually accessible wastes. Furthermore, since GPR can also retrieve the material properties of objects [7], this technique can be extended to enable discrimination of hidden waste base on their material properties e.g. liquid radioactive plumes and depleted uranium from expended ammunitions.

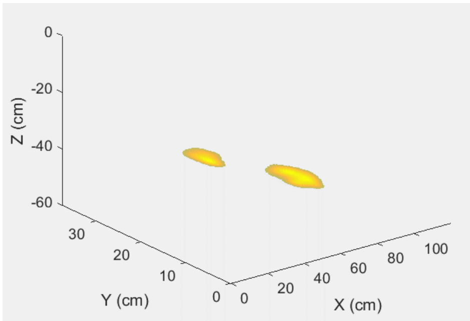

Figure 3: 3D localisation of the sources

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