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# 3D localization of radioactive sources by triangulation method using a single gamma camera

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Localization of radioactive sources is a major concern in the nuclear industry whether in decommissioning phases of nuclear facilities, nuclear waste management applications, radiation protection or Homeland Security. Therefore, gamma imaging emerges as a measurement solution that allows localizing and identifying radioactive sources in near and far field, which reduces the dose received by operators and hence respecting the ALARA principle.
Gamma cameras based on hybrid pixel detectors such as Timepix3 [1] technology, enables the localization of radioactive hot spots by superimposing a gamma image on a visible image. The last generation of gamma camera developed at the CEA List is Nanopix, a very compact gamma camera that allows remote localization, visualization and gamma spectrometry measurement of radioactive hot spots. With a weight lower than 400 g and a size of 8×5×5 cm3, Nanopix is currently the smallest coded aperture camera in the world.
However, this generation of gamma imager has two main limitations considering its deployment in complex radiological environments. Indeed, the localization of hot spots requires maintaining a stationary measurement position. In addition, the two-dimensional reconstructed image provides information about the direction of the source, but does not allow a direct estimate of the distance to the source. The work presented here aims to overcome these limitations to have a system able to estimate the three-dimensional localization of a hot spot.
The imaging technics used in our applications are based either on the principle of spatial encoding by coded aperture, or on the principle of Compton scattering kinematics. As part of the work, these two techniques have been adapted through algorithms to provide a spatial localization of hot spots in three-dimensions. The developed method requires moving the gamma camera as sort to know every single position according to every gamma image reconstructed.
The results obtained by Monte Carlo simulations, and then by experimental measurements, show the capacity Nanopix to locate in three-dimensions radioactive sources emitting gamma rays from 59.5 keV (241Am) to 1.33 MeV (60Co) at distances from 60 cm to 500 cm with uncertainties below 10 %. The results obtained with Nanopix and the techniques developed in this work pave the way for 3D radiological mapping of crowded and unknown areas.

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