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SORIS—A standoff radiation imaging system

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ABSTRACT

The detection of radiological and special nuclear material within the country's borders is a crucial component of the national security network. Being able to detect small amounts of radiological material at large distances is especially important for search applications. To provide this capability General Electric's Research Center has developed, as a part of DNDO's standoff radiation detection system advanced technology demonstration (SORDS-ATD) program, a standoff radiation imaging system (SORIS). This vehicle-based system is capable of detecting weak sources at large distances in relatively short times. To accomplish this, GE has developed a novel coded aperture detector based on commercial components from GE Healthcare. An array of commercial gamma cameras modified to increase the system efficiency and energy range are used as position sensitive detectors. Unlike typical coded aperture systems, however, SORIS employs a non-planar mask and thus does not suffer the typical limitations of partially encoded regions giving it a wide field of view. Source identification is done using both low-statistics anomaly indicators and conventional high-statistics algorithms being developed by Pacific Northwest National Laboratory. The results of scanned areas and threats identified are displayed to the user and overlaid on satellite imagery.

As a part of the defense against possible radiological and nuclear weapons it is necessary to be able to detect radioactive isotopes at very large distances. Approaches that rely merely on the intensity of the detected radiation at the location of the detector however, are easily confounded by the natural variations of background radiation and, if a source is identified, are able to provide only a crude indication to the isotope's location. A system that can detect and localize threats would be of great benefit, since it would be able to distinguish between these sources and the more distributed background radiation sources.

The stand-off radiation imaging system (SORIS) has been designed to provide this localization capability. Once a source is localized, isotope identification algorithms will identify the source based on its spectral signature. The system is designed to be compatible with a variety of mobile platforms and is currently installed in a commercial van (Fig. 1).

Similar to other previous [1] and concurrent [2,3] approaches, localization of the radiological sources utilizes a coded aperture detector. The detector is composed of a position sensitive detector (PSD) and an active mask. For coded aperture systems [4,5], the mask projects a shadow pattern on the PSD that shifts position depending on the source's location (see Fig. 2). Coded aperture designs are appealing due to the relative simplicity of their construction and their ability to resolve multiple radioactive sources.

Standard coded apertures, however, suffer from two main limitations. First, the system efficiency is low because the mask absorbs 50% of the gamma-rays incident on the system. Second, the detector's field of view (the fully encoded region) is limited and is determined by the size of the mask, the size of the PSD and their separation. Increasing the size of the encoded region is possible either by increasing the mask size or decreasing the mask-PSD separation. The former will decrease the overall efficiency since a smaller fraction of the total system size is sensitive to radiation, while the latter will require a corresponding decrease in the PSD pixel size to give a similar angular resolution.

SORIS's hardware design addresses these limitations. First, the mask has a curved multi-tiered arrangement. The curved mask enables a wide field of view and eliminates any partial encoding in the plane of motion. Therefore any sources at oblique angles will be resolved with high accuracy and minimal artifacts. The multiple complimentary tiers provide information to determine the elevation of the source. While additional smaller tiers would improve the spatial resolution of the source's reconstructed elevation, the number chosen allows a balance between system complexity and achieving the desired resolution. The elevation

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Fig. 1. SORIS system (lower left) before installation in the van and (lower right) after installation. Top is a rendition showing the system's relative placement after installation.

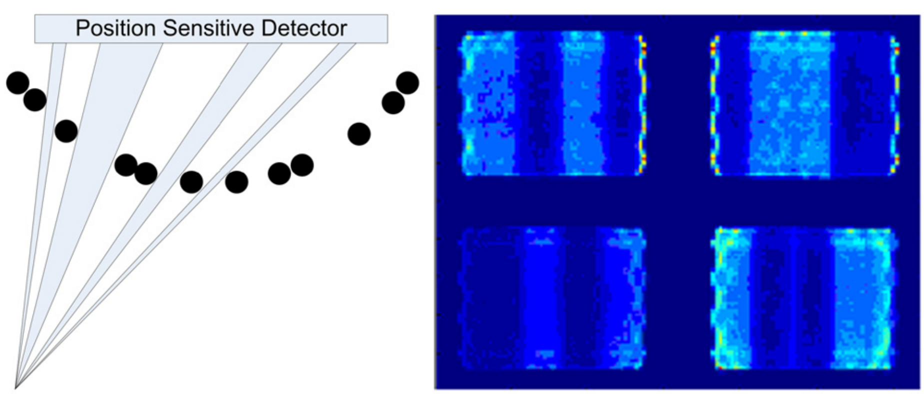

Fig. 2. Left: basis of coded aperture camera operation. The radiation is partially occluded by the mask that is then detected by the position sensitive detector. Right: sample image recorded on the PSD, composed of the four gamma cameras, after exposure to a ^{137}Cs source. Shadow of the two complimentary tiers of the mask is apparent.

resolution is sufficient, for example, to determine the level of a building where a threat is located. In addition to the enhanced filed-of-view due to the curved mask, this design also decreases the overall footprint of the detection system allowing it to be operated from a common cargo van or other conveyance, such as air or sea craft. The vehicle chosen for this implementation is a cargo van up-fitted with commercially available fiberglass side-panels. The fiberglass panels ensure minimal radiation attenuation even at low gamma-ray energies.

The second limitation of coded aperture systems, the inherent lower efficiency, is addressed by constructing the coded mask with an active NaI scintillator. Unlike a passive mask, which discards absorbed gamma-rays, an active mask is able to detect the gamma-rays absorbed in the mask for threat analysis and isotope identification. We employ an active mask composed of 23 3 inch diameter NaI rods. The rods serve the dual purpose of providing attenuation to the incident radiation for localization and for being able to provide spectroscopic information for isotope identification.

The PSD is composed of an array of four gamma cameras. Each gamma camera is single 3 in. thick NaI plate (60 cm × 46 cm) read out by 96 photo-multiplier tubes (PMTs). A gamma that interacts with the scintillator plate deposits its energy, which is converted to light. This light is detected by multiple PMTs and the position is calculated using Anger logic. The energy of the gamma is determined by summing the signal from multiple PMTs. In this manner the PSD with a 3 in. NaI crystal has better spatial resolution than 10 mm for determining the gamma-ray interaction point and 8% energy resolution for 662 keV gammas corresponding to a ^{137}Cs source. The gamma cameras are read out using GE Healthcare's electronics, whereby all 96 PMT signals are amplified, digitized and the incident gamma-ray's energy and position is determined. An interface board in the data acquisition computer directly reads out this information.