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Development of Fast Compton/Coded-aperture Hybrid Gamma-ray Imaging System for Application in Port, Airport, and Bonded Warehouse

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1. Introduction

For the detection of nuclear and radioactive materials in imported cargo, radiation portal monitors (RPMs) and handheld survey meters are currently used at borders, including ports, airports, and bonded warehouses [1]. However, these devices lack imaging capabilities, making it time-consuming to locate nuclear or radioactive materials accurately. This limitation not only slows down customs work but also compromises safety risks. To overcome the limitation, in this study, a Fast Gamma Imager (FGI) was developed. The performance of the developed system was then evaluated with various experimental conditions.

2. Methods and Results

The FGI was designed to meet the critical need for rapid identification and localization of radioactive materials in challenging environmental conditions, such as vast, complex, and variable sites. The main feature of the FGI is the use of a high-sensitivity imaging module, which comprises two large-area scintillation detector heads, a mechanical collimator, and two contextual sensors to scan the surrounding environment in 3-D while moving freely. To localizes the radioactive materials in cargo the FGI used a hybrid gamma imaging technique that combines Compton imaging and coded aperture imaging. The hybrid imaging was implemented by pixel-wise multiplication of the images obtained from the two methods. This study applied hybrid imaging to all gamma rays, regardless of their energy levels. To synthesize the performances of coded aperture and Compton imaging for high SNR imaging.

Experiments were conducted to compare the performance of the FGI with that of a Polaris-H420 [2] (H3D Inc., MI, USA), a commercially available imager suitable for hand-held applications. To compare the performance of the H420, the localization time of the developed FGI was tested at various dose rates (0.001–0.028 µSv/h). The dose rate was controlled by adjusting the position and activity of the ^{137} Cs source. The mean localization time, defined as the average time taken to localize the source from the gamma-ray image over repeated measurements, was evaluated. The number of iterations was set to 100 measurements. Figure 1 shows the evaluated identification times for the FGI and H420. The localization time of the H420 was evaluated to be 83 s for a dose rate of 0.028 µSv/h when a 10 µCi ^{137}Cs source was positioned 1 m in front of the system. Under the same conditions, the localization time of the FGI was only 0.62 seconds, making it 133 times faster than the H420. Even under lower incremental dose rate conditions (0.74 µCi ^{137}Cs source at 2 m or 0.0005 µSv/h incremental dose rate), the system imaged the location of the source within 300 seconds.

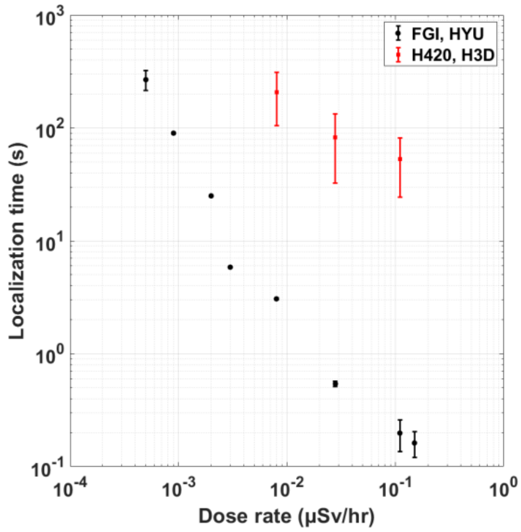

Fig. 1. Comparison of identification time between the FGI and the commercial gamma imager (H420).

3. Conclusions

In the present study, the FGI was developed to localize the radioactive at customs fields, including ports, airports, and bonded warehouses. Experiments demonstrate the ability of the gamma imaging system to quickly and accurately localize the nuclear and radioactive materials in cargo. The high-speed gamma imaging system is expected to improve the time-consuming localization process of radioactive contaminants, given the limitation of the existing radiation detection devices at airports and harbors, which lack imaging capabilities, thereby reducing the risk of transporting nuclear or radioactive materials.

REFERENCES

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