

# THE UTILITY OF X-RAY DUAL-ENERGY TRANSMISSION AND SCATTER TECHNOLOGIES FOR ILLICIT MATERIAL DETECTION

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## (ABSTRACT)

X-ray devices have demonstrated the ability to characterize a material at the molecular and atomic levels. This ability is particularly important for detecting plastic explosives, where object shape information cannot be used. X-ray devices are relatively inexpensive compared to many other detection technologies. X-ray technology is considered as the technology for detecting illicit materials. Using x-ray technology, a material's *density*- and *effective atomic number* or  $Z_{eff}$ -related information can be determined. In theory, an illicit material can be identified using those two pieces of information.

This dissertation discusses explosives detection in passenger luggage bags. The x-ray technology used is called  $R$ - $L$  multi-sensing technology. The  $R$ - $L$  technology was developed by researchers at Virginia Tech. It is the first true multisensing technology used for explosive detection. It uses dual-energy transmission and scatter technologies to obtain characteristic values of an object, *i.e.*,  $R$  and  $L$ . The material type of this object can then be determined using  $R$ - $L$  plane. The characteristic value  $R$  is computed using signals from dual-energy transmission modality.  $R$  is related to  $Z_{eff}$ . The characteristic value  $L$  is computed using signals from low-energy transmission and scatter modalities.  $L$  is related to density. Compared to single-sensing technologies and pseudo multi-sensing technologies, the detection accuracy of  $R$ - $L$  technology should be much higher.

The  $R$  and  $L$  values of an object can only be computed from an object's true gray levels. True gray level refers to the measured gray level of an object when it is not overlapped with any other objects. The problem is objects in a bag almost always overlap with other objects. Being able to identify the object of interest and remove the overlap effects becomes the key issue that needs to be solved.

The discussion in this dissertation focuses on the development of the image-processing system used on this multiple sensor system. This image-processing system is comprised of four steps. The first step is to spatially register images from all the sensing modalities. The second step is to remove noise using the edge-preserving smoothing algorithm. The third step is to segment image into regions with relatively uniform gray levels. The fourth step is to compute the true gray levels for objects of interest using the mathematical models for removing overlapping effects. Most of the research focuses on developing a robust segmentation algorithm for segmenting x-ray bag images and developing mathematical models for removing object overlapping effects. The unique contribution of this dissertation includes the development of those mathematical models used for removing object-overlapping effects, and the development of the algorithm for determining an object's true gray levels.

The experimental verification shows that the algorithms for registration, smoothing, and segmentation work well. The algorithm that computes the true gray levels of an object can perform the computation quite precisely in transmission modality. However, the methods that were developed for computing an object's true gray levels in scatter images are much less accurate.

## **ACKNOWLEDGEMENTS**

First and foremost, I would like to thank my advisor, Dr. Richard W. Conners, for his immeasurable guidance, patience, and support throughout the course of my Master and Ph.D. studies. I have learned much as a direct result of working with him. In addition, his confidence in my capability has enabled much of my creative work as well as diligent working habits.

I would also like to thank Dr. A. Lynn Abbott, Dr. D. Earl Kline, Dr. James R. Armstrong, Dr. Scott F. Midkiff, and Dr. Jeffrey H. Reed for their helpful advice and for being on my committee. Financial support during my studies was mainly provided by Federal Aviation Administration and is greatly appreciated. Warm thanks to Dr. Thomas H. Drayer, Yuhua Cui, Shubing Zou, Xinhua Shi, Panos J. Arvanitis, Nanpeng Chen, Wei Xie, Paul Lacasse, Hongliang Wu, Jinhua Shan, and all the people who have worked with me on the project at the Spatial Data Analysis Laboratory. I would like to thank Jun Xu, and all my other friends in Blacksburg for their friendship and support during my Ph.D. studies. I express my special gratitude to Dr. Shiu Cheung at the FAA Research Center for providing invaluable support.

Special thanks to my parents Zuyin Lu and Runsheng Zhu for their high standard on my academic career and strict discipline on my early education. My father, who passed away several years ago, still has deep influences in every aspect of my academic career and my life. I also dedicate this dissertation to my sister Dr. Bin Lu and my brother Dr. Feng Lu for their support and understanding.