Chapter 8. Conclusions and Future Research

X-ray detection technology is unique in its ability to provide operators with a detailed image of the contents of bags. By using different algorithms, x-ray sensing can also provide important information about the composition of materials. In recent years, x-ray based systems have increasingly been used as an effective means for the automatic detection of explosives. While a number of devices are now commercially available, most of these technologies are not yet mature. The purpose of this research has been to investigate methods for using x-ray dual-energy transmission and scatter imaging technologies more effectively.

First, a model for a prototype x-ray scanning system, which was built at SDAL, is given. This model has primarily been used for the purpose of system analysis, design and simulations. We use this model to predict some system errors, and to assist in developing the algorithms for treatment of such errors. This model was also used to provide data in copper filter design and in the development of a numerical method for eliminating thickness effect.

In the prototype scanning system, the pixel values are varied for the same object due to the non-uniformity of the transmission detectors. A lot of measurements are done, and an algorithm is developed to correct this non-uniformity.

The x-ray source output energy in the prototype scanning system is not monochromatic; it has a distribution over a wide range. To meet the design requirement on developing this dual-

energy x-ray scanning system, two problems have to be dealt with. The first one is the overlap of the x-ray spectrum between high energy and low energy, which will degrade the performance of dual-energy. The second one is the unbalance of output signals applied with high energy and low energy. This is due to the limited dynamic signal range of x-ray scanning system. A copper filter has been introduced and developed to improve the system performance.

The back scattering and forward scattering signals are functions of solid angles between the object and detectors. A given object may be randomly placed anywhere on the conveyor belt, resulting in a variation in the detected signals. Both an adaptive modeling technique and least square's method are used to decrease this distant effect.

A numerical optimization method has been developed to improve a dual-energy x-ray scanning system for those using x-ray tube sources, where a continuum energy distribution of x-rays is emitted. Thus the restriction is that it is only possible to obtain a dual-energy transmission images at two particular x-ray energy bands, not two particular x-ray energies. The advantageous for the numerical method over existed dual-energy systems are as follows: 1) provide the x-ray attenuation at two x-ray energies, thus greatly improve the material characterization; 2) turn to be a real dual-energy system, and can be easily extended to a multiple energy system. Parametric analysis method is used to estimate the improvement on materials characterization by using the approaches mentioned above with some typical testing materials.

Classification rules are obtained to separate explosives from others. Discriminate function methods have been experimentally studied.

Materials characterization using x-ray technology has been a very active and important research topic in recent decades. The FAA has been spending hundred of millions of dollars

to support such a research effort in order to improve the civil and commercial air traffic safety. Any little bit of improvement on this research is of significance, and will not be neglected. The research work presented in this dissertation represents a step toward this direction. Possible further research followed with this dissertation is recommended in the following.

The current numerical method is based on the approaches of the unconstrained optimization. Optimization itself is a major branch in system engineering. There are a lot of topics which may be further studied. One is to explore the constraint optimization approaches in x-ray imaging system design. In that case, we may use the principles of x-ray interaction with matter as a constraint to get a better performance in term of convergence speed and precision. Others may be to investigate the fast real-time implementation algorithms and the global convergence point, and so on.

From our experimental tests, it was found that there is some overlap between innocent materials and explosive simulants in (R, L) space. This can be improved if we are able to compute a thickness-independent L. Much more efforts might be needed to address this issue, since the mathematical model for scattering is very complicated than that of transmission. The breakthrough on this problem will make a great contribution to the object classification in (R, L) space.