AI Models of X-Ray Baggage Screenings

A technical review of machine learning techniques for X-ray baggage screening, develop model, train and test model and implementation.

- Aviation security in context

Before the COVID-19 pandemic, the aviation industry in 2019 was generating 65.5 million jobs and it share in the global economy was estimated at $ 2.7 trillion, equivalent to 3.6% of the world gross domestic product. In the same year, 4.3 billion passengers were carried by airlines worldwide, which was an increase of 6.4% from 2017. In the US, there were over one billion air passengers in 2019: an increase of 3.8 % compared with 2018. (Source: Statistica.)

- Aviation Security Policies

Common basic Standard comprise (Source: US Govt, Accountability Office)

- screening of passengers, cabin baggage and hold (checked) baggage
- airport security (access control, surveillance)
- aircraft security checks and searches
- screening of cargo and mail — screening of airport supplies
- staff recruitment and training.

There has been a need for the screening of passengers and their baggage for three main purposes:

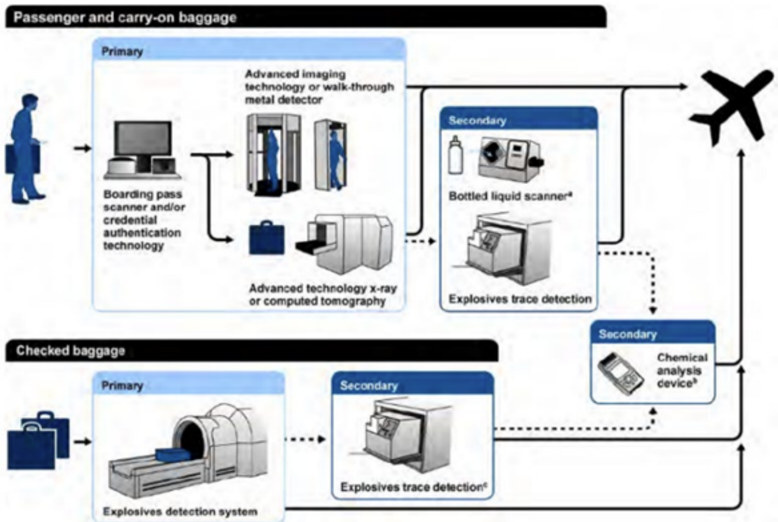
- the illegal movement of goods or prohibited items according to the local legislative procedures
- fraud and revenue avoidance
- terrorist threat

2.1 Project Purpose

In this project we will focus on security screening x-rays. A passenger may be examined by these technologies and by human operators in primary and secondary screening. The primary screening of humans is performed using walk-through metal detectors and full-body, millimetre-wave scanners. In this project, we focus on threats located in the baggage.
Primary screening of baggage is X-ray based and consists of two types of screening:

- visual inspection of X-ray technology based scans for prohibited items
- automated object detection

2.2 Typical workflow in US airport. (Source: US Govt. Accountability Office)



Airports strive to automate technologies and detection processes to improve effectiveness while reducing scanning and image processing times and human error, and while rightsizing the number of personnel needed at the checkpoint. X-ray based techniques are the main technology used at checkpoints. There are 2D and 3D X-ray scanners for screening of both hold baggage and cabin baggage, and there exist different techniques to process the scans depending on types of threats. X-ray diffraction (XRD) is sometimes used, although current deployment levels of XRD are very low. In order to perform security screenings fast and securely enough, new solutions are constantly emerging trying to adapt to the reality of content of travel baggage and to new security threats which emerge as technology develops.

3. Principles of X-Ray screening

Objects in visible-spectrum images are opaque and occlude each other. On the contrary, X-ray images are transparent. X-rays penetrate the objects; therefore, the objects along the X-ray path attenuate the signal and affect the final intensity value. Therefore, pixel intensities in X-ray images represent signal attenuation due to (multiple) objects. The contrast between objects in X-ray images is provided by the differential attenuation of the X-rays as they pass through the objects. For X-ray transmission, the attenuation of X-rays as they travel through objects is formulated by:

$$I_x = I_0 e^{-\mu x}$$

where I_x is the intensity of the X-ray at a distance x from the source, I_0 is the intensity of the incident X-ray beam, and μ is the linear attenuation coefficient of the object, measured in cm^{-1} . The higher the density of the material, the higher the value of μ, and the higher the attenuation. Hence, high-density materials, like metals, attenuate the X-rays more; as a result, the measured intensity becomes lower and the image gets darker. The simplest X-ray method for screening baggage is radiographic X-ray imaging. It can be done either by a single radiographic shot with a large area imager, or by a continuous X-ray exposure and using an X-ray line sensor. Generally, the line scanning method is used to screen cabin baggage. It requires only a limited area to be irradiated by X-ray and since the carry-on items are continuously travelling on a conveyor belt, it allows continuous scan and storage of the X-ray image of the whole baggage. Because the irradiated area is a narrow line, it is much easier to shield the X-rays than in the case of a single

shot X-ray system, where the whole object is illuminated
4. Final Project Scope and Steps

1. **Data Collection**:
    - Gather a large dataset of X-ray images containing both normal and prohibited items (such as weapons, explosives, and sharp objects).
    - Annotate the images to label the presence or absence of prohibited items.

1. **Preprocessing**:
    - Clean and preprocess the X-ray images to enhance their quality.
    - Normalize pixel values and resize images to a consistent resolution.

1. **Model Selection**:
    - Choose an appropriate deep learning model for object detection.

1. **Model Architecture**:
    - Design a custom model or work with a pre-trained model.
    - Add layers for object detection and classification.

1. **Data Augmentation**:
    - Augment the dataset by applying transformations (rotation, scaling, etc.) to create additional training samples.

1. **Training**:
    - Split the dataset into training, validation, and test sets.
    - Train the model using the annotated X-ray images.
    - Optimize hyperparameters (learning rate, batch size, etc.).

1. **Evaluation**:
    - Evaluate the model's performance on the validation and test sets.
    - Metrics could include precision, recall, F1-score, and accuracy. Test for bias.

1. **Fine-Tuning**:
    - Fine-tune the model based on evaluation results.
    - Address false positives and false negatives.

1. **Model Implementation**