

CONTAINER STRIPPING: ENHANCED CLASSIFICATION OF MATERIALS WITHIN CARGO CONTAINERS

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Abstract

For cargo and vehicle inspection, where high energy linear accelerators are used, materials within radiographic images can be classified using their atomic number (Z). The identification and classification of materials and objects within cargo containers can be difficult, due to the nature of energy spectra and their impact on the discrimination of materials. This can also be impacted by system-level factors, such as the stability of the linear accelerator and the alignment of the system. By removing the container from images of cargo, materials inside can be classified with higher confidence. When a low- Z , low density organic material is obscured by a steel container, its effective- Z value changes and it can colourise as green rather than orange. This could lead to mis-classification of materials by an operator, potentially leading to the mis-identification of threatening materials. Further to the container removal, extra layers can be ‘stripped’ away to better reveal certain areas of interest. In future, this could be tied in with operator-assisting algorithms, as part of an enhanced image quality analysis package.

INTRODUCTION

Material discrimination is a key aspect of radiographic images in the security industry, as it allows operators to determine the material classification of cargo contents. In high-energy security applications, materials are usually categorized into four groups: low- Z organic, low- Z inorganic, high- Z inorganic (metals) and very high- Z materials. These are tested using graphite, aluminium, steel, and lead which are coloured orange, green, blue, and purple respectively. Materials are coloured based on their effective- Z value (effective atomic number). IEC 62523 is a recognised standard within cargo inspection. Figure 1 shows the materials that need to be coloured correctly in order to pass this material discrimination test [1].

Material \ Thickness mm	T1	T2	T3	T4	T5
lead	10	20	40	60	100
steel	15	30	60	90	150
aluminium	40	80	160	250	400
graphite	100	200	400	600	N/A

Figure 1: IEC 62523 material discrimination test thicknesses.

Most customers in the security market opt for 3-layer material discrimination (graphite, aluminium, and steel). This is most often tested using sugar for low- Z organic, salt for low- Z inorganic and steel for high- Z inorganic (metal).

Material Stripping

The term ‘Material Stripping’ refers to stripping homogenous layers of material from cargo inspection images, revealing the layer(s) behind. The evident first step in the process is ‘Container Stripping’, i.e., removing the cargo container from the image. A standard ISO shipping container is made of steel, and each of the sides are around 5 mm thick.

All objects within the container are obscured by this 10 mm of steel, which has the potential to impact the effective- Z value of the objects. By stripping the container, the true effective- Z value of the cargo inside can be identified and displayed.

As a 6/4 MeV pulsed linac is used, both ‘high’ and ‘low’ images are produced. In order to strip a material from an image, a correction factor needs to be applied. The correction factors are found using Eqs. (1) and (2):

$$F_H = \frac{65535 \cdot 0.95}{S_H} \quad (1)$$

$$F_L = \frac{65535 \cdot 0.95}{S_L} \quad (2)$$

Where S_H and S_L are the mean high and low signal values of the area to be stripped. The $(65535 \cdot 0.95)$ is referred to as the ‘air ceiling’ – this is 95 % of the maximum signal value.

Previous Work in The Field

Some work has been done previously on Material Stripping. Chen et al. conducted ‘virtual layer peeling’ where they found hidden objects by peeling away steel shielding from images [2]. They found that structural information from the objects was preserved, and the correct materials were revealed.

US Patent no. 2023/0076255 A1 [3] focusses on the process of selecting 2 regions in an x-ray image, essentially an area to use for averaging and another area to be stripped from the image. The area can only be stripped if the uniformity of the values in the region to be used for averaging falls within a predefined range. This patent looks at theoretically stripping different thicknesses of steel away from organic materials and looking at the effect this has on the effective- Z values.

RESEARCH AND METHODOLOGY

In this research, x-ray images of cargo were taken during the commissioning stage of Rapiscan | AS&E’s M60 (Mobile) systems. Scan data was also used from previous systems, including P60 (Portal) and G60 (Gantry) systems. To manipulate the high and low energy images, a MATLAB

code was created. An unobscured section of container is selected, and the average signal value taken to give S_H and S_L in Eqs. (1) and (2) above. Then the correction factors are found and applied to a larger section of the image (in this case, the whole container). This strips away the container, i.e., sets the signal values of the container to air values. In

Fig. 2, this can be seen as the container was blue (steel) pre-stripping, and post-stripping this has changed to grey/white (air). The final step is to apply the system's material discrimination calibration file to the new image, revealing the new (and true) effective-Z of the contents of the cargo container.

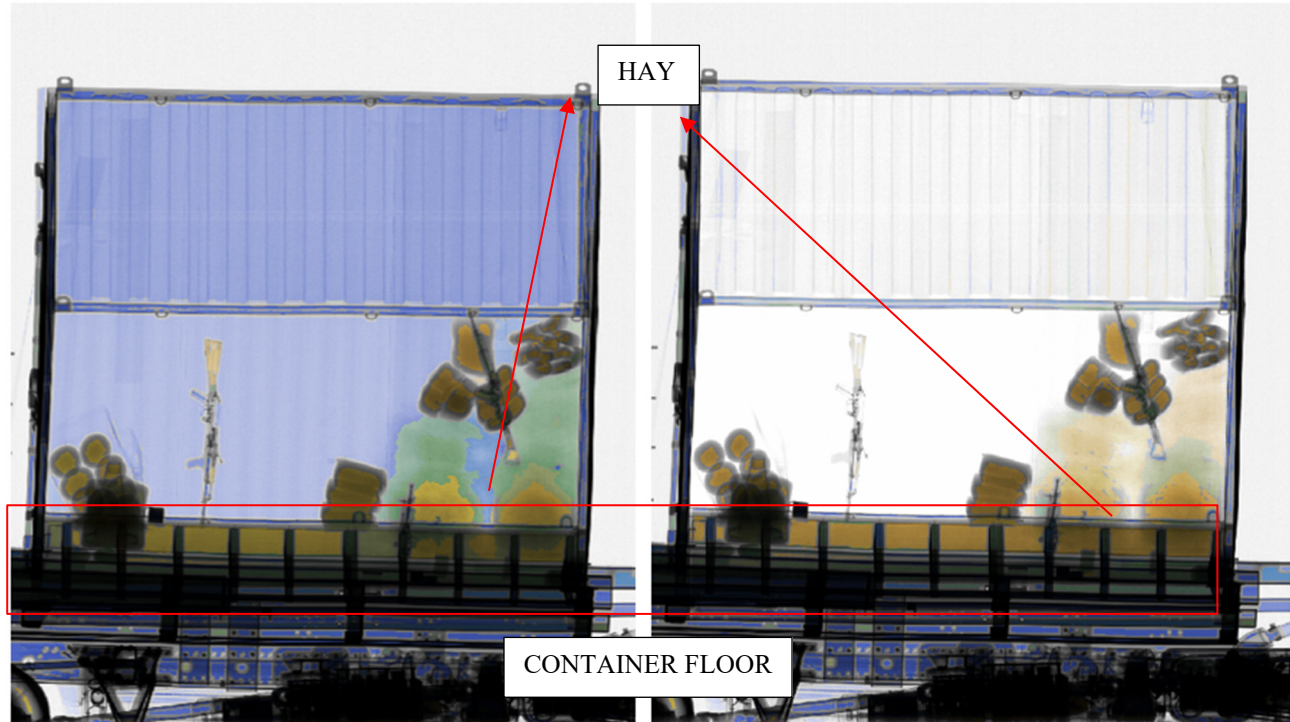


Figure 2: Cargo pre-and post-container stripping.

RESULTS AND ANALYSIS

It was found that stripping away the container proved to be a viable solution to reveal the true effective-Z value of the contents of a cargo container. Figure 2 shows a side-by-side comparison of the same cargo pre- and post-container stripping. It can be seen that the contents of the cargo have been better revealed by stripping away the container. The most obvious example in this container is the hay on the right-hand side of the container. Before stripping the container, the hay is mostly green (inorganic), however hay is an organic material. When the container is stripped, the true effective-Z value of the hay is revealed and the majority of it is now coloured correctly. Another good indication that the stripping routine has worked is the change in colour of the container floor. Containers usually have wooden floors, and once the container has been stripped the true effective-Z is revealed (the floor becomes a brighter orange colour).

Overall, the results have been successful. Many examples have been tested, and in most cases the correct effective-Z contents of the container has been revealed. A few examples include water-filled drums, pallets of paper and

bags of salt and sugar inside of the container. Container Stripping has proved to be very good at revealing low attenuating objects, implying it can reveal low density threats.

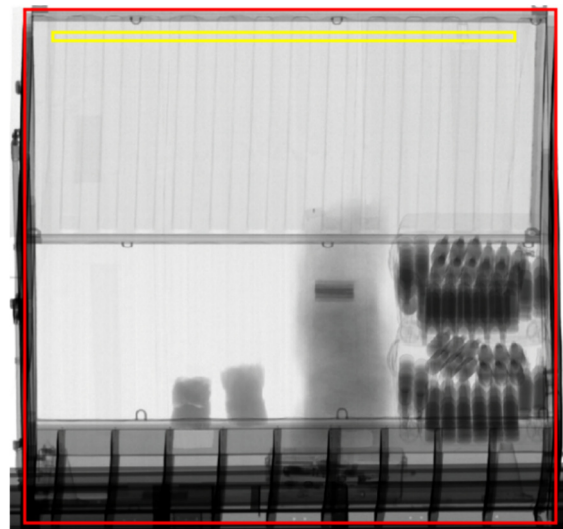


Figure 3: Region (yellow) used for stripping.

Container Stripping ROI

A very small section of the container can be used to successfully strip the container away. The yellow section seen in Fig. 3 contains enough data to average and obtain reliable S_H and S_L values. This is very promising for the real-world application, as in most scenarios only the very top of the container will be unobscured.

Multi-layer Stripping

Once the container has been stripped, other layers of cargo can be stripped to reveal hidden objects. This is referred to as ‘Multi-layer Stripping’. In the left-hand side of the container in Fig. 2, there is a plastic traffic cone hidden behind another object. Figure 4 shows this traffic cone revealed, by using the same routine, just for a smaller area. Previously, the traffic cone was appearing as mostly green. After stripping, the effective-Z of some regions are shifting more towards organic. However, there are still more overlapping materials, such as the container floor, so the traffic cone has not been revealed as completely organic.

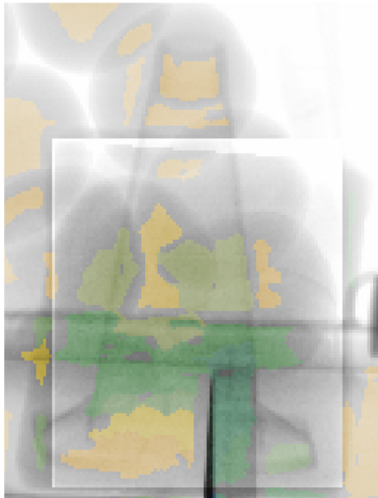


Figure 4: Traffic cone revealed.

Stripping multiple layers is more difficult than just stripping the container, which is one (mostly) homogenous material in the image. Where multiple layers are involved, the signal values have already been changed due to the initial container stripping. Further to this, it is difficult to find a section of the overlapping material large enough to use for averaging. Beam hardening can also occur, and this further obscures the effective-Z values, skewing them away from their true value. The addition of beam hardening correction factors would reduce this effect.

CONCLUSION

In cargo inspection, materials are classified using their effective-Z values and are typically split into 3-layers (low-Z organic, low-Z inorganic and high-Z inorganic).

Currently, all contents of a cargo container are obscured by the container walls. By stripping away the container, the true effective-Z values of the contents can be revealed. To do this, a small region at the top of a full container can be used to average signal values and successfully strip away

the entire container. After the container has been stripped, it is possible to strip multiple other layers within the cargo. This is done using the same process as container stripping but is more difficult as the areas available for averaging are usually much smaller. Both ‘Container Stripping’ and ‘Multi-layer Stripping’ have provided promising results and work effectively.

In future, both of these techniques shall be refined so that they operate in a way that is operator-friendly, without impacting image quality.

REFERENCES

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