ACXIS – AUTOMATED COMPARISON OF X-RAY IMAGES FOR CARGO SCANNING

Alexander Flisch[1], Thomas Lüthi[2], Mathieu Plamondon[3], Stefan Hartmann[4], Wicher Visser[5], Adrian Schwaninger[6], Diana Hardmeier[7], Marius Costin[8], Caroline Vienne[9], Frank Sukowski[10], Ulf Haßler[11], Irène Dorion[12], Andrea Canonica[13], Eric Rochat[14], Ger Koomen[15], Micha Slegt[16]

[1] alexander.flisch@empa.ch, [2] thomas.luethi@empa.ch, [3]mathieu.plamondon@empa.ch, [4]stefan.hartmann@empa.ch
EMPA. Swiss Federal Laboratories for Materials Science and Technology, Center for X-ray Analytics, Überlandstrasse 129, 8600 Dübendorf (Switzerland)

[5] wicher.visser@casra.ch, [6]adrian.schwaninger@casra.ch, [7]diana.hardmeier@casra.ch
Center of Adaptive Security Research and Applications (CASRA), Thurgauerstrasse 39, 8050 Zürich (Switzerland)

[8] marius.costin@cea.fr, [9] caroline.vienne@cea.fr
CEA LIST, Department of Imaging & Simulation for Non-Destructive Testing, 91191 Gif sur Yvette (France)

[10] frank.sukowski@iis.fraunhofer.de, [11] ulf.hassler@iis.fraunhofer.de
Fraunhofer Institute for Integrated Circuits IIS, Development Center for X-ray Technology EZRT, Flugplatzstrasse 75, 90768 Fürth (Germany)

[12] irene.dorion@smithsdetection.com
Smiths Heimann S.A.S. (SH), 36, rue Charles Heller, 94405 Vitry sur Seine (France)

[13] andrea.canonica@ezv.admin.ch, [14] eric.rochat@ezv.admin.ch
Swiss federal Customs Administration (FCA), Montbijoustrasse 40, 3003 Bern (Switzerland)

[15] gcm.koomen@belastingsdienst.nl, [16] m.slegt@belastingsdienst.nl
Dutch Tax and Customs Administration, Dutch Customs Laboratory (DTCA), PO Box 3070, 6401 DN Heerlen (Netherlands)

Abstract

The ongoing FP7 project "ACXIS - Automated Comparison of X-ray Images for cargo Scanning" delivers enhanced inspection procedures for customs. A manufacturer independent reference data base for X-ray images of illegal and legitimate cargo is developed. One of the X-ray image recording work flow is to use 3D-CT data of illegal cargo mockups and to artificially generate arbitrary X-ray projections. By merging these X-ray projections and radiographic images of cargo freight containers with legitimate goods a high number of reference images can be obtained in a very efficient way. Based on these images an analysis system is developed consisting of image pre-processing methods as well as automated target recognition (ATR) algorithms supporting the inspection officer by identifying threat items automatically and highlighting them in the X-ray image.

Keywords: Cargo screening, ATR, X-ray, imaging, image processing,

1 INTRODUCTION

Government and citizens expect the customs authorities both to impede the import of goods that endanger public safety and to prevent import tax evasion. The predicament of the customs administrations will soon be aggravated by both the increase of global trade and the trend towards 100% screening. Therefore, a significant increase of the cargo inspection capabilities is essential for Europe to keep its position in the global trading and transportation network. It is therefore a goal to develop new inspection concepts to enable faster cargo handling at customs.

A viable solution for more efficient and effective cargo screening is an automated analysis system for the X-ray images supporting the inspection officer with automated illegal cargo and threat detection. To implement the adjustability on the local context as well as the activities to fight organised crime, a data base system has to be established in which X-ray images and meta-information of both historic detection and mock-up cargo are stored and exchanged between customs organisations. Given the variety of systems currently installed at European customs offices, the new automated detection system improves the current detection capabilities if it operates manufacturer-independently and provides a reliable detection for different scanner types and application fields.

Different scenarios for the support of the inspection officer are conceivable. First, images of historic detections based on the cargo declaration are displayed alongside the current cargo image to facilitate a direct comparison. Second, the system automatically analyses the image and highlights in the image presented to the inspection officer regions of interest where a closer inspection is required. Third, in a future development step, the system will independently inspect uncritical cargo, i.e. empty containers, and forward the inspection task to a human operator only in case of ambiguous results. Current training consists in the identification of a small set of critical cargo elements superimposed on historic images of the inspection system. A draw-back of this system is the adaption of the inspection officer to the small set of training images that are usually limited due to factors like confidentiality of the image data. The set of training images is significantly enhanced if artificial cargo image can be generated with arbitrary positioning of objects in the image data base.

In this project, a risk analysis will be conducted in close collaboration between end users (customs organizations), scientists and security experts in order to define threats to be detected in different cargo screening scenarios. A large and representative data base containing cargo X-ray images will be developed. Modern image and signal processing algorithms will be applied and further developed for automated detection of threats in X-ray images using different signatures based on material, structure and shape information. Applied visual cognition research will be used to identify how expert screeners recognize threats in order to further enhance automated detection and screener assist technology. The highly innovative system will be implemented using a simulator to be used in the field by end users in order to ensure operational relevance, practical evaluation and further refinement of the system.

2 IMPROVED INSPECTION PROCEDURES

In the scope of ACXIS, automated target recognition (ATR) functions are developed to analyse images issued from X-ray scans of cargo shipments inspected at land, air or sea border crossing points. With the new procedures proposed by the ACXIS project, the Customs officers will carry out the inspection helped by ATR functions available on-demand. They will be able to annotate the results and to share them with other agencies through a secure system. The X-ray data will be converted into a standardized format and stored in a database along with the results of the ATRs and other annotations (Figure 1). This standardization allows comparison between scans from X-ray machines of different manufacturers and models. The database is loaded with a large array of reference material and new scans are continuously integrated.

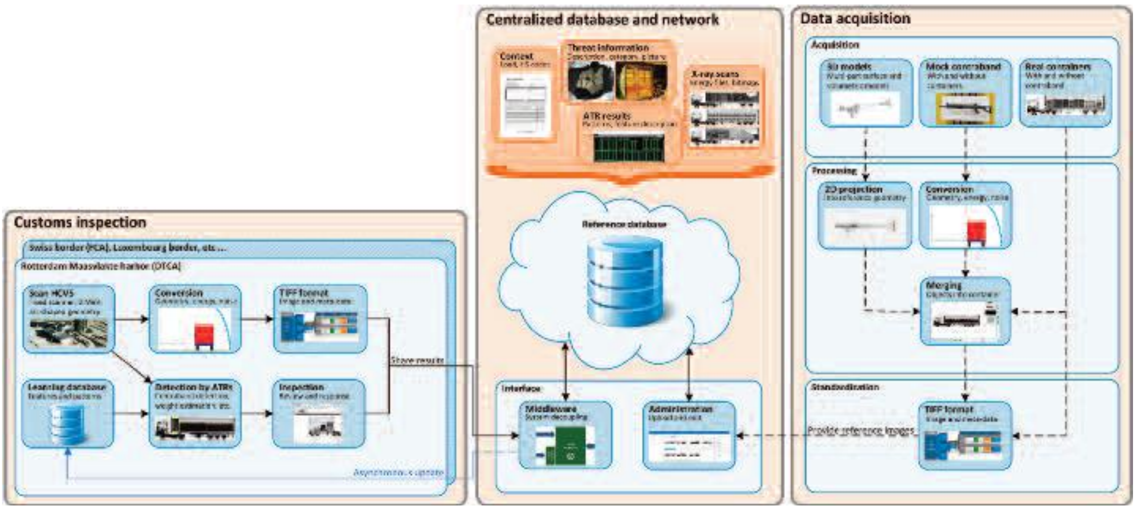

Figure 1: X-ray inspection procedure for border controls with automated target recognition functions based on a centralized database

3 REFERENCE DATABASE

Based on risk analysis conducted by the Customs administrations, threat objects and their locations in the container were identified. Following their recommendations, a set of mock-ups was created with real threat items and simulants, combined with common goods (Figure 2).

These were scanned using laboratory systems, and some with a cargo scanner, chosen as reference. The main objective of these mock-up scans was to enlarge the variety of threat images. For the same purpose, simulation tools were also used in order to generate X-ray images from 3D models of various types of threat items (e.g. weapons).

Between all classes of threats, few more details are given on two items. Tobacco products are principally legal, but with a fairly high taxation on them. Therefore it can be interesting to bring untaxed cigarettes in large amounts to the black market. Due to the relatively low density, the cigarettes themselves are hardly visible behind more massive materials; however, their packaging has a certain texture that can be detected. Another class of risk items if the shielding containers of radioactive Gamma-ray sources, used generally in the field of non-destructive testing (NDT). The transport of such containers is legal, but needs an adequately equipped and identified vehicle as well as specially trained drivers. The heavy shielding necessary for such sources is made from lead or depleted uranium and therefore, creates opaque regions on the X-ray image because of the high attenuation of the beam. These areas are visually analyzed, but automatic algorithms could also be employed.

All the images from the database and especially the ones containing threat items will provide a large basis for training of screening officers and also for machine learning methods in automated detection algorithms.

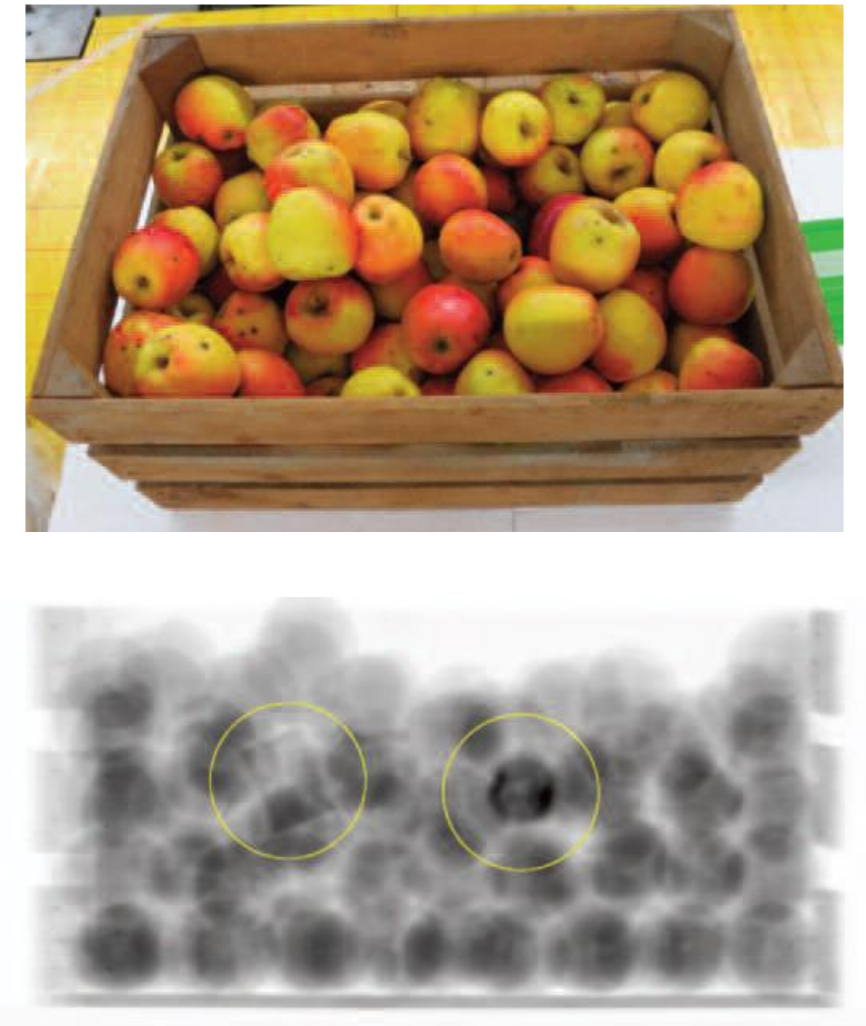

Figure 2: Example of images containing threats. Plastex and hand grenade hidden between apples. Photo (top) and X-ray image (bottom)

4 IMAGE UNIFICATION

When analysing X-ray images, the human brain easily adapts to other different systems, regardless the possible geometric deformations, various textures and different levels of contrast or noise, which is not the case for automatic algorithms. Since a large variety of X-ray scanners are installed at border checkpoints, the analysed images need to be similar in terms of the aforementioned parameters. Standardising these images is a preparation step and is mandatory for good detection performances.

Physical processes involved in digital X-ray imaging were studied and accurate models were developed in order to take into account the differences between the various X-ray scanners. Geometric adaption is perhaps the most challenging since projecting a complex load from distant view angles generates different distortions in the resulting image. However, an approach which selects the most similar ray paths and makes use of the standardised container dimensions gives satisfactory conversion results as shown in Figure 3. The example shows a conversion of a Euromax image (top) to a SH-HCVS image appearance (middle) that looks very similar to a genuinely obtained SH-HCVS image (bottom).

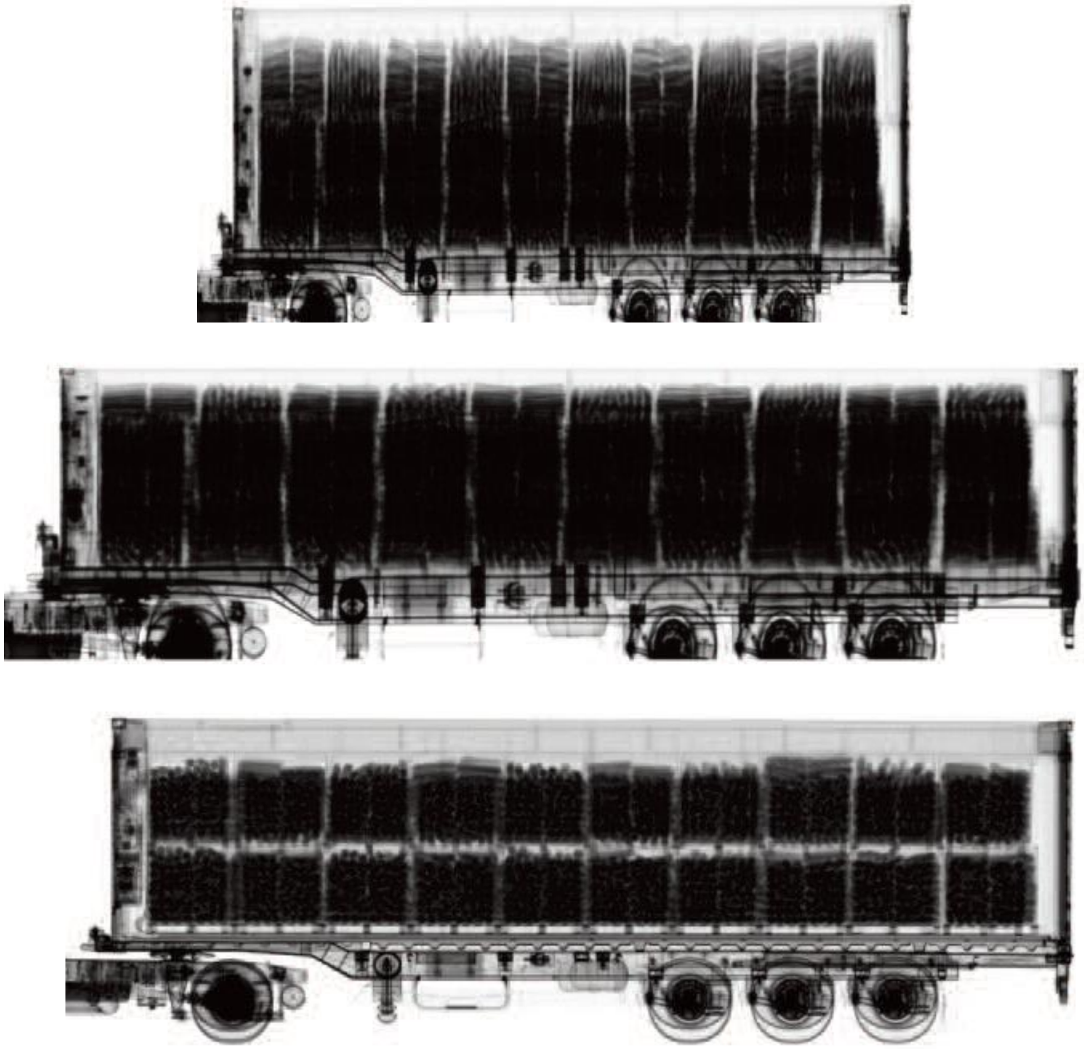

Figure 3: Real container scan with Euromax (top) and SH-HCVS (bottom) scanners. The Euromax scan was converted to the SH-HCVS format (middle)

Contrast corrections take into account the source spectra and typical phantoms are used to estimate several attenuation points, which are then fitted in order to use the obtained curves for adjustments of grey level values. Several noise reduction algorithms were evaluated in order to select the best one to reduce the noise to the level of the reference scanner, without affecting the image quality (e.g. the texture of the sharpness).

5 AUTOMATED TARGET RECOGNITION

The ultimate goal is to provide assisted / automated detection techniques of threats through dedicated algorithms. Several illicit goods detection scenarios were selected and prioritized. Several approaches of complementary assisted / automated detection techniques have been investigated according to the various envisioned scenarios, such as image comparison, load characterization and direct target recognition.

5.1 Automated Detection of Cigarettes

Methods for cigarettes detection based on texture analysis are being developed and show promising results. For instance the load in Figure 4 is automatically identified as cigarettes packs and a warning is displayed to the screening officer.

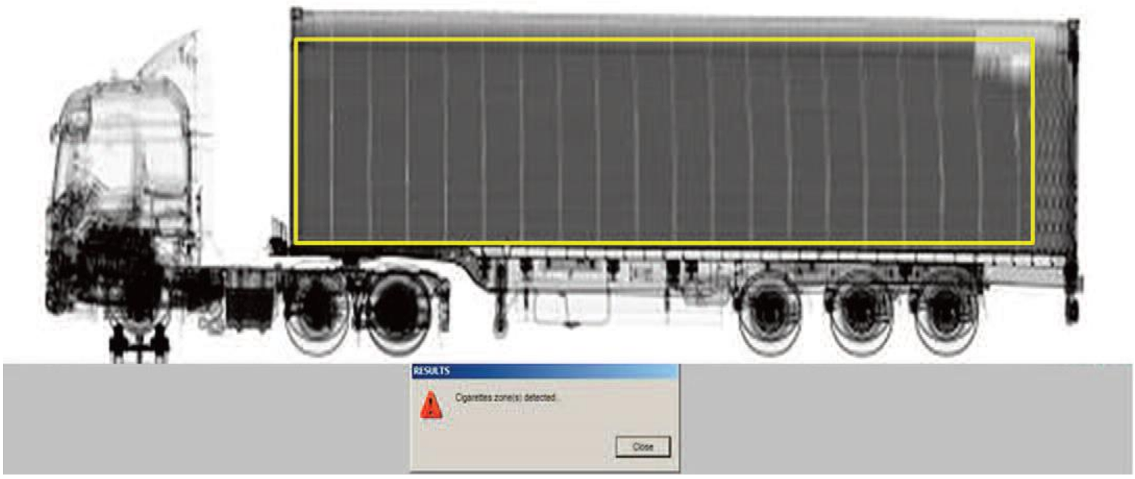

Figure 4: Example of automated detection of cigarettes

5.2 Weight Estimation

A tool to help the operators to analyze the load of a cargo container is the weight estimation. In the process of analyzing the load, it is often helpful to match areas on the X-ray image of the load with the goods marked on the waybill. This software tool will give an indication of the actual weight to be compared with the declarations, as shown in Figure 5

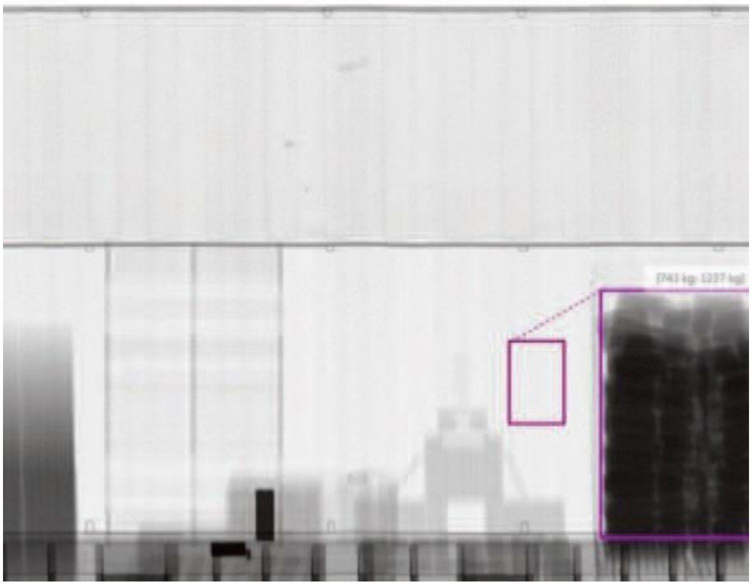

Figure 5: Tool for weight estimation of loads in a cargo container

5.3 Image Irregularity Detection

Instead of searching to detect specific threats which might be missed because of their large variety, a very helpful approach is to detect irregularities. A tool has been developed which will point out areas showing irregularities which will then be analysed in detail by the screening officer. Through advanced image processing algorithms employing registration techniques, a difference image with respect to a reference will give indications of irregularities, a indicated in Figure 6.

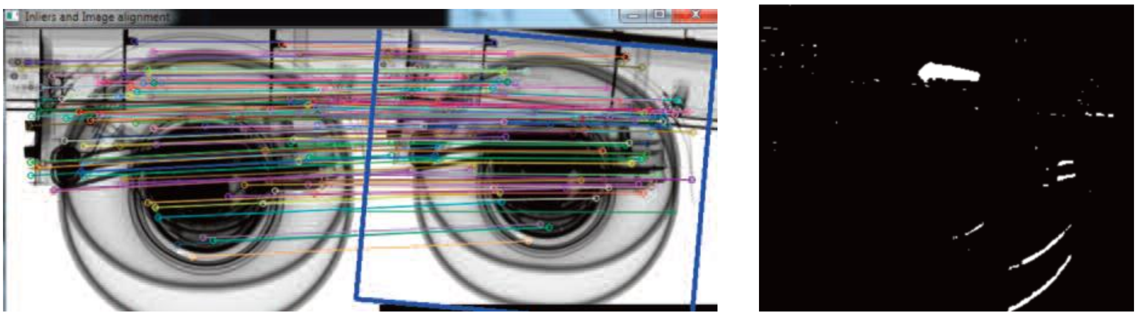

Figure 6: Automatic detection of an irregularity by comparison with reference image: registration process and indication on a difference image

6 TRAINING THE CUSTOMS OFFICERS AND VALIDATION

A software application is developed to provide focused training on X-ray image interpretation and decision making, and to periodically evaluate the performance of Customs officers (Figure 7). The user interface is carefully designed to resemble various X-ray scanning systems, and includes the most important support functions, such as zooming, image filters and enhancements. The behaviour of the ATR functions are simulated with the placement of coloured frames in the image that indicate the possible existence of suspicious goods. The user receives feedback upon making decision whether the cargo should be subject to further inspection, informing him whether his answer was correct and which suspicious goods are part of the cargo.

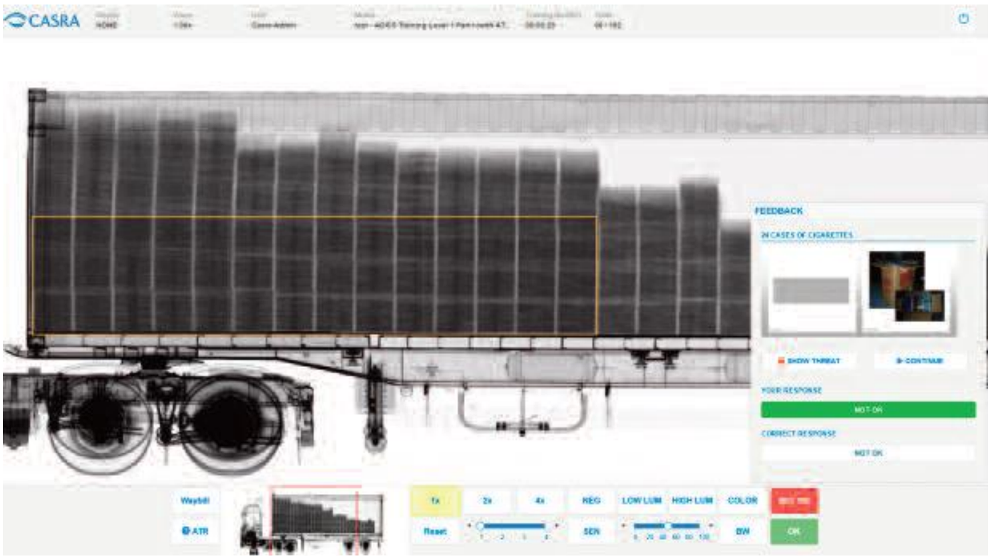

Figure 7: Educating the experts: training with the simulator

The impact of the ATRs on the performance of Customs officers is evaluated through a validation study. A group of operators is selected for training during which they are presented with simulations of X-ray scans of shipments that are annotated with the detection results of the ATRs. The performance of these participants are compared against a control group.

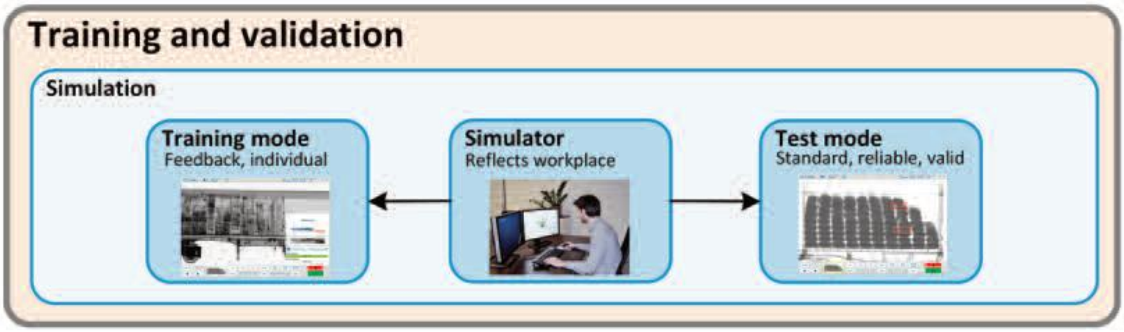

Figure 8: The simulation software provides X-ray interpretation training and tests for customs officers

Training and test modules have been developed for the simulation software (Figure 8). The training modules automatically adjust the training difficulty to the level of expertise of the user. Supervised learning is guaranteed by providing the user with feedback after each image. The test modules are standardized packages that enable reliable and valid means to carry out initial and recurrent evaluation of Customs officers. These methodologies are rooted in behavioral psychology and have been applied to airport security personnel for many years with great success.

ACKNOWLEDGEMENTS

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