SCIENCE & SECURITY Issue 28

CASRA NEWSLETTER

It is time to publish our second newsletter in 2022!

Since 2012, we have been publishing newsletters in which we present results from our research, address trends, and provide information for security practitioners.

In this issue, we present as part of a comprehensive research project how Automated Prohibited Items Detection Systems (APIDS) can potentially upgrade X-ray and CT machines when combined with automated explosive detection. The second article presents a major new feature for CASRA's web-based computer-training platform X-Ray Tutor 4 (XRT4). The XRT4 Theoretical Block allows now to run various e-learnings, theoretical exams, and questionnaires.

We hope you enjoy reading these new articles and as always, we are looking forward to receiving any feedback you might have as well as your input on topics you would like us to address in upcoming newsletters.

With best wishes,

Dr. Diana Hardmeier
Director

Prof. Dr. Adrian Schwaninger
Chairman

TOPICS IN THIS ISSUE:

RESEARCH PUT ACROSS

COMMERCIALLY AVAILABLE APIDS (AUTOMATED PROHIBITED ITEMS DETECTION SYSTEMS)

With the advance of computer vision in recent years, X-ray and CT machines can now be upgraded with APIDS (Automated Prohibited Items Detection Systems). When used in combination with automated explosive detection, it could become possible in the future that primary screening of cabin baggage can be done automatically without the need of human inspection, at least for a share of the baggage. CASRA has surveyed commercial providers of APIDS. The results of this survey are presented in this article.

SECURITY IN PRACTICE

XRT4 - NEW FEATURE - THEORETICAL BLOCK

In the past few years, we have been working on our new all-encompassing training and testing solution X-Ray Tutor 4 (XRT4). XRT4 allows you to select, train and test X-ray security officers with single-view, dual-view images as well as 3D computed tomography technology. For enabling people and technology for a safe and secure world even more, we developed a new feature called theoretical block. This allows customers to run various e-learnings, theoretical exams and questionnaires within XRT4.

COMMERCIALLY AVAILABLE APIDS (AUTOMATED PROHIBITED ITEMS DETECTION SYSTEMS)

Text: Yanik Sterchi, Céline Delay

The screening of cabin baggage still relies on human operators (screeners) inspecting X-ray images for prohibited items. When explosive detection systems (EDS) were introduced, the detection of threats in cabin baggage was no longer solely dependent on visual recognition by screeners – which is good news, considering that screeners have difficulties with detecting explosives without a triggering device [1]. Automated Prohibited Items Detection Systems (APIDS) represent a further step towards automating primary screening. Fueled by rapid developments in computer vision in the last decade, these systems can now detect guns and knives by not only relying on material information but also considering their shape. With the potential to automate a large share of X-ray and CT image inspection, APIDS have the potential to become a disruptive development in screening technology – for airports, security providers, but also for us at CASRA with screener training and performance as the main focus of our research and products.

INTRODUCTION: WHAT ARE APIDS?

Artificial intelligence, machine learning, and deep learning are terms that are related to APIDS (Figure 1). The term artificial intelligence (AI) "comprises any technique that enables computers to mimic human behaviour and reproduce or excel over human decision-making to solve complex tasks independently or with minimal human intervention" [3]. Machine learning is a subfield of AI where a "computer program's performance improves with experience with respect to some class of tasks and performance measures" [3].

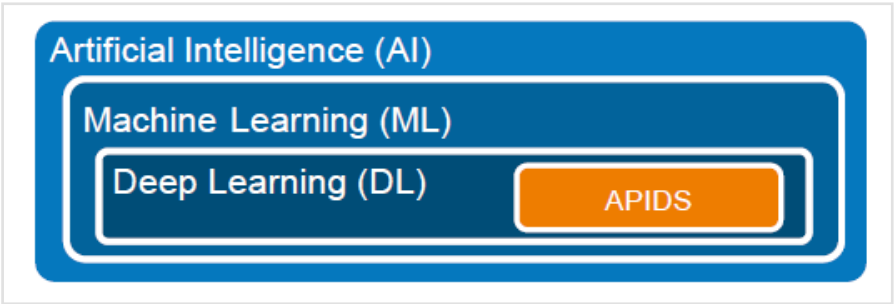

Figure 1: APIDS can be understood as a specific application of deep learning.

Deep learning is a subfield of machine learning that involves deep (artificial) neural networks with many layers of processing units and can therefore outperform other machine-learning algorithms for most applications of image processing (given that there is enough training data available) [1].

Thanks to the increase in computational processing power and developments in neural network architectures, deep learning has driven big advances in computer vision. This has led to multiple scanner manufacturers as well as third party companies developing specific deep learning applications for the detection of prohibited items in X-ray and CT images. Since APIDS are currently a new technological advancement, opportunities and risks are yet to be researched. As part of a comprehensive research project (TRAI: Target Recognition Using Artificial Intelligence), which investigates these opportunities and risks, CASRA has surveyed commercial providers about their algorithms.

PROCEDURE AND SURVEY PARTICIPANTS

First, online sources on APIDS were reviewed. In a second step, ten providers of APIDS were contacted at the end of 2021 and asked to first provide written answers to a list of survey questions and to then participate in a short follow-up interview. Out of the ten contacted APIDS providers, the following eight participated in the survey:

- Dimensionless Technologie
- IDSS – Integrated Defense and Security Solutions
- Leidos
- Neural Guard
- Rapiscan (formerly Synapse Technology)
- SeeTrue Screening
- Smiths Detection
- Steep GmbH

RESULTS

In this section, we summarize the information reported by the surveyed providers.

COMPOSITION AND COMPATIBILITY

The surveyed providers offer APIDS for both 2D X-ray and 3D CT systems, but not all providers cover both systems. Four providers offer systems for 2D X-ray single-view as well as multi-view and 3D CT scanners. One provider only has an APIDS compatible with X-ray systems, and two providers each offer an APIDS tuned to a certain model of 3D scanner.

Providers reported that the APIDS either run directly on the X-ray or CT ma-

chine, on a separate machine (typically connected via VGA, DVI, HDMI, display port, or ethernet), or on a server used for centralized image processing / remote screening.

Most third-party providers offer APIDS for several models of X-ray / CT machines from leading manufacturers like Astrophysics, IDSS, Leidos, Rapiscan, or Smiths Detection. Due to direct integration, some APIDS are solely compatible with specific machine models. APIDS from scanner manufacturers were mostly only available for their own brands.

FUNCTIONALITY AND PERFORMANCE

Essentially all APIDS can detect guns, knives, and other sharp objects. Many APIDS also detect gun parts (e.g. ammunition or magazines), hand grenades, bottles, or electronic devices (e.g. laptops).

The providers reported detection rates above 90% for almost all items. Thereby, the detection rate for guns is slightly higher than that for knives. False alarm rates vary from close to 0% up to 10%. On average, the false alarm rates are below 5%. However, these numbers are difficult to compare, as no unified standards for measuring the performance of these APIDS exist yet.

Providers reported that APIDS usually process images between under one or a few seconds, whereby the processing takes slightly longer for CT scanners than for X-ray machines.

As it is also the case with human screeners, how well APIDS detect threats not only depends on the threat itself but can also depend on various characteristics of the X-ray image. For example, strong superposition can reduce detection and many prohibited items are detected worse in certain orientations. Compared to single view X-ray machines, orientation and superposition are less of an issue for multi-view machines and even less of an issue in 3D CT images.

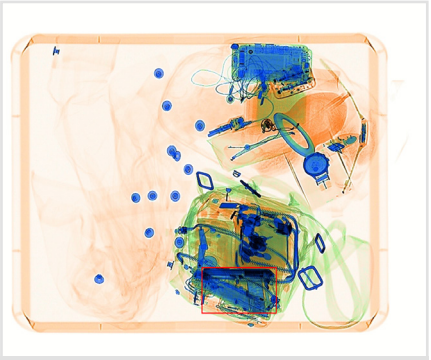

Figure 2: Illustration of a gun detected by an APIDS.

Usually, when the APIDS detect a possible threat in images, a frame (bounding box) marks the prohibited item on the operator's screen. In case of 3D images, many providers offer an optional voxel overlay that can be turned on or off. Whether the category of the detected prohibited item is displayed, can be customized for most APIDS.

TRAINING OF APIDS

One of the biggest challenges in the development of APIDS is the large number of images of baggage containing annotated prohibited items for training the algorithms. As most providers state, thousands if not tens of thousands of images are required to train an APIDS to recognize a certain type or category of prohibited items (depending on the complexity and variety of those items).

About half of the providers trained their algorithms exclusively with real images, which are time-consuming and costly to produce. The other half used a mix of real and synthetic recordings to reduce the effort associated with real recordings. However, most of the providers can imagine using synthetic data in the future. One provider, on the other hand, believes in the advantages of using only real images.

Providers are typically willing to include additional categories of prohibited items if requested by the customer and if sufficient training material can be made available.

TESTING, INTERFACES AND ARCHITECTURE

If the currently common approach to regulatory testing and certification is followed, APIDS will have to be certified for each machine type separately and will have to be recertified if changed. If an APIDS should be extended to detect an additional category/type of prohibited items, it might be possible to add a separate algorithm and thereby avoid the requirement of recertifying the entire APIDS.

Because APIDS will be continuously improved over the upcoming years, the surveyed providers would prefer a process for the recertification of APIDS based on previously recorded images and emulators. However, this would require one or several standardized interfaces between the scanners and the APIDS. Third-party providers of APIDS reported that their 2D algorithms used captured RGB images as input and their 3D algorithms used the DICOS standard, whereas the APIDS of scanner manufacturers rely on images in their proprietary formats.

COST AND IMPLEMENTATION

Currently, APIDS are not yet rolled out widely but are being piloted at various airports. Pricing models are therefore not yet fully fixed for many APIDS, but providers reported a variety of possible options, from prices per unit or licence to subscription payments or prices per scan, with often multiple pricing models

offered by the same provider. Prices will of course also depend on whether also hardware, updates, warranties and/or support are included.

The implementation of APIDS is generally fast and easy. Most do not need a calibration specific to APIDS beyond the usual calibration of the X-ray or CT machines whereas others apply some minor adjustments.

Most companies have not yet developed a standardized procedure for routine testing of their APIDS.

CURRENT SITUATION AND OPEN QUESTIONS

According to providers, their APIDS are ready for deployment and have the potential to increase both the security and efficiency of baggage screening. Meanwhile, APIDS are currently only allowed to assist screeners, who would still need to inspect each image, which limits the incentive for airports to invest in APIDS. Or, depending on local regulations, the use of APIDS is not yet allowed at all. It is also not clear yet, how screeners should resolve alarms, how they should be trained to effectively collaborate with APIDS, or which information an APIDS should provide to screeners for optimal performance.

Despite several open questions, things are moving forward. Currently, a first airport is trialing automated image inspection with APIDS and EDS. Thereby, a certain percentage of bags are randomly selected for automated screening and only inspected by screeners in case of an alarm by the EDS or APIDS. Also, a first certification standard for APIDS is under development in Europe. With the arrival of APIDS on the horizon one might wonder: Will screeners soon only look at images that triggered an APIDS or EDS alarm (sometimes referred to as alarm-only viewing)? Predicting the future is difficult, but APIDS certainly have the potential to reduce the number of images that must be inspected. In the short run, screeners might still be needed to look for prohibited items that are not yet covered by APIDS (a first certification standard will likely only focus on the most dangerous threats like guns, gun parts, and knives). Because it is also not clear yet how quickly detection of new threats can be incorporated into APIDS, the detection of new threats might also remain a task of screeners. Even after APIDS might cover the full range of prohibited items, screeners will still be needed for correctly resolving the alarms.

CONCLUSION

Thanks to advances in computer vision it is now possible to implement and make use of APIDS at airports. According to providers of APIDS, their products are ready to be deployed. However, certification standards are needed and several questions regarding the human-machine interaction should be answered to allow for a wide implementation of APIDS at airports. The TRAI project aims at supporting this process by research on important open questions.

If you are interested in the topic, please do not hesitate to contact CASRA at info@casra.ch for the full report. CASRA would like to thank all APIDS providers for their valuable contribution.

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[3] Janiesch, C., Zschech, P., & Heinrich, K. (2021). Machine learning and deep learning. *Electronic Markets, 31(3), 685-695.*

XRT4 - NEW FEATURE - THEORETICAL BLOCK

Text: Sarina Baumgartner

In the past few years, we have been working on our new all-encompassing training and testing solution X-Ray Tutor 4 (XRT4). XRT4 allows you to select, train and test X-ray security officers with single-view, dual-view images as well as 3D computed tomography technology – an all in one solution.

XRT4 is highly flexible and configurable and supports different user interfaces. Customers can also upload their own images to create customized training and testing courses. Besides being single-view, dual-view, and 3D CT compatible, XRT4 supports the computer-based training and testing of security officers in various areas of operation, up to large-scale truck screening in customs. More areas will be added regularly, so please contact us if you want to learn more.

Figure 1: XRT4 has been enriched with a new feature called theoretical block.

To better support the training and testing of various threats or behavior, CASRA (Center for Adaptive Security Research and Applications) developed a new feature called theoretical block (TB) last year. TB enables customers to run various e-learnings, theoretical exams (such as multiple-choice questions) and questionnaires. Unlike other Learning Management Systems, TB is fully embedded in XRT4, meaning that users already created can be used without additional effort and data and results appear in the XRT4 reports.

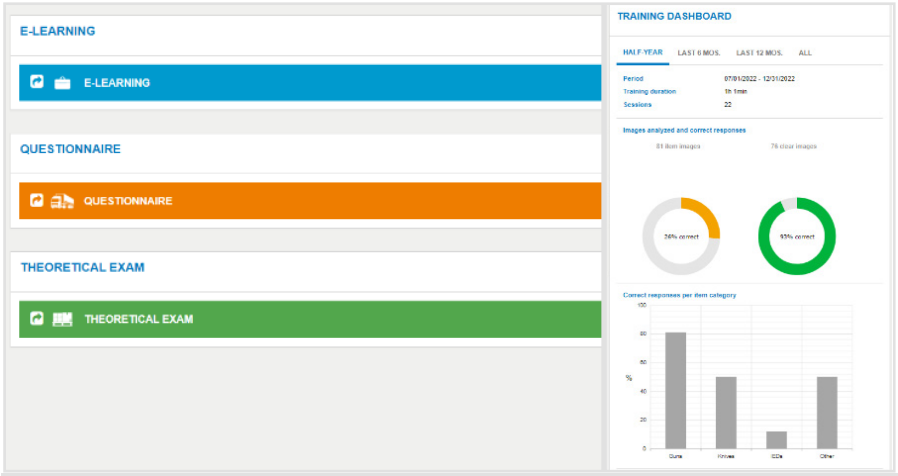

Figure 2: Home screen of XRT4 with various modules and training dashboard

SUPPORTED CONTENT TYPES

Overall, the theoretical block supports three different content types:

- E-Learning
- Theoretical Exam
- Questionnaire

E-LEARNING

XRT4 supplies functionality to run e-learning modules. E-learning offers an effective and efficient way to expand theoretical knowledge. With e-learning modules it is for example possible to train or expand general theoretical knowledge as well as to prepare for theoretical exams.

In contrast to theoretical exams, pictures, videos and the like can be displayed in e-learning. The user can be shown continuous text as well as common question types (Figure 3). This means that e-learning can be tested directly with a small quiz. The difference, however, is that the e-learning is not evaluated, henceforth a pass mark is not set, and the reporting function will only

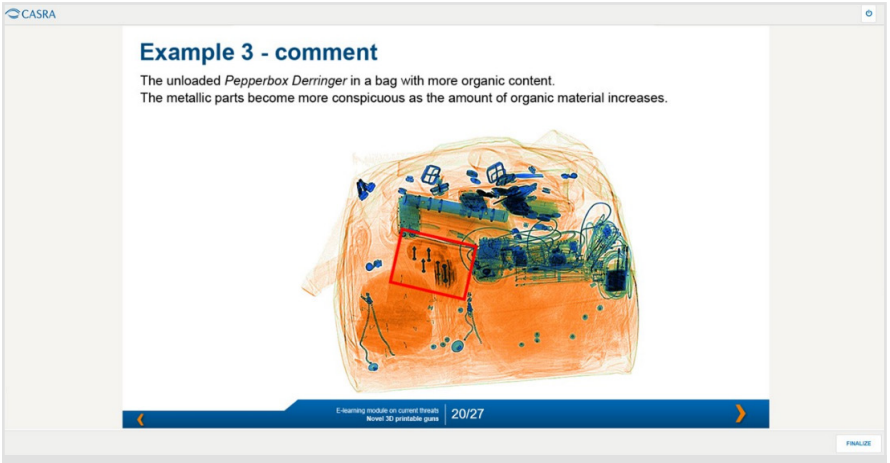

Figure 3: Example of an E-Learning slide within XRT4.

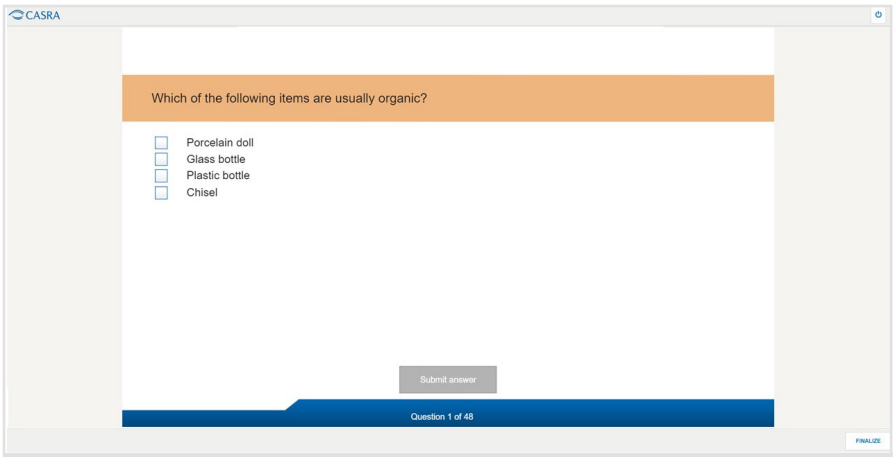

Figure 4: Users view for a theoretical exam within XRT4

show whether the e-learning was fully completed and how much time the user spent on the e-learning.

For example, our systematic threat assessment e-learnings, which describe new and emerging threats and how to recognize them, are now also being made available via TB. In addition, some customers are already using the possibility of generating their own in-house e-learning courses and making them available to their screeners.

THEORETICAL EXAM

XRT4 supplies functionality to execute and evaluate a theoretical exam as an addition to the image interpretation test. Theoretical exams can consist of a wide variety of question types, such as multiple choice, single choice, fill in the blank, matching question types, etc. and can be used for theoretical certifications, test preparations or customer-internal theoretical competence measurements (Figure 4). A theoretical exam can also be combined with a prior knowledge transfer (videos, images, animations).

During the theoretical exam, pass marks can be set, allowing an automatic evaluation of which tests have been passed and which ones must be repeated. Additionally, the detailed reporting system shows which questions were answered correctly and incorrectly per user, as it is essential for the application and evaluation of the theoretical exam to gather such data.

QUESTIONNAIRE

XRT4 supplies functionality to define and conduct questionnaires, such as, employee surveys, collecting feedback or for research purposes. This form of the TB is very well suited, as a wide variety of question types are supported, such as open questions (text answers, ...), matrix questions (dissatisfied, neutral, satisfied) as well as multiple and single choice questions. Figure 5 displays such matrix question.

The results of the questionnaires can be analyzed using the report function.

This feature gives customers the ability to run internal questionnaires directly in XRT4 - all in one central location. In a questionnaire, for example, the usability of a simulator, feedback to a changed working process or employee related human resources changes can be inquired directly. Additionally, the questionnaires can also be used by our researchers to carry out their study questionnaires in the XRT4 application.

CONTENT INTEGRATION PROCESS

Similarly, to the XRT4 Expert license, which provides customers with the functionality to create their own X-ray content, presentations and modules, to complement the ones created by CASRA, own courses can be uploaded in the TB.

Embedding such courses in XRT4 is a straightforward process, via an authoring tool (e.g., Adobe Captivate, iSpring or others) which is needed to create your own modules. These authoring tools enable you to export your existing e-learnings or tests in standard formats such as SCORM, xAPI or cmi5.

Courses created in the authoring tool can be uploaded to XRT4 and used accordingly (Figure 6). The definition of the evaluation of individual question types takes place in the authoring tool and is taken over by XRT4. A minimum score,

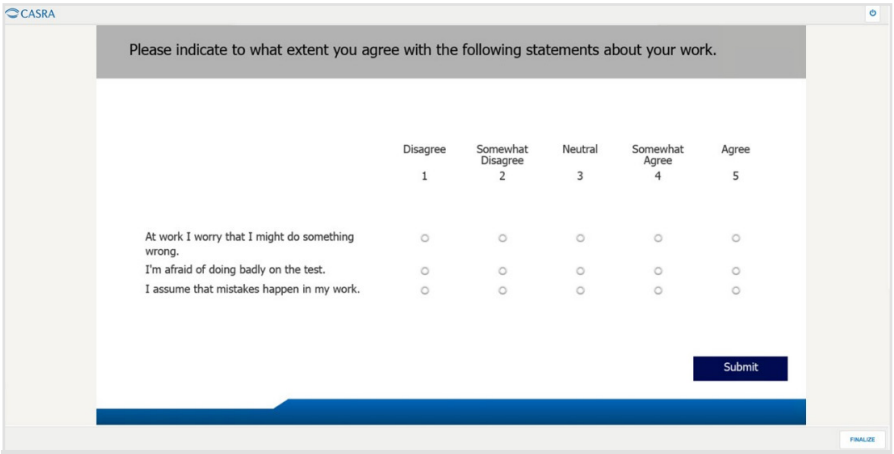

Figure 5: Example of how a questionnaire within XRT4 could look like

Figure 6: XRT4 supports various standard formats of authoring tools

which must be achieved for theoretical exams, for example, can be defined in the authoring tool but overwritten in XRT4 if necessary.

These modules can then be assigned to the corresponding user group or individuals and will automatically appear in the user's home screen page (see first image) when logging in so that the user/s will be able to run them. Within the module settings it is possible to either enable or disable direct feedback to the user about passing or failing a course (if a pass mark is set), as visible in Figure 7.

The in-built reporting system offers you the possibility to review detailed results via several report templates. Such reporting system retrieves various data, such as which users completed which courses and when, as well as the time spent on the module and the status of a module. It can also include more detailed data, such as the score achieved, whether a test was passed or failed, and even at the lowest level of granularity, the answers per question.

Should you be interested in knowing more about our new feature, please don't hesitate to contact our customer relations and sales team:
customerrelations@casra.ch

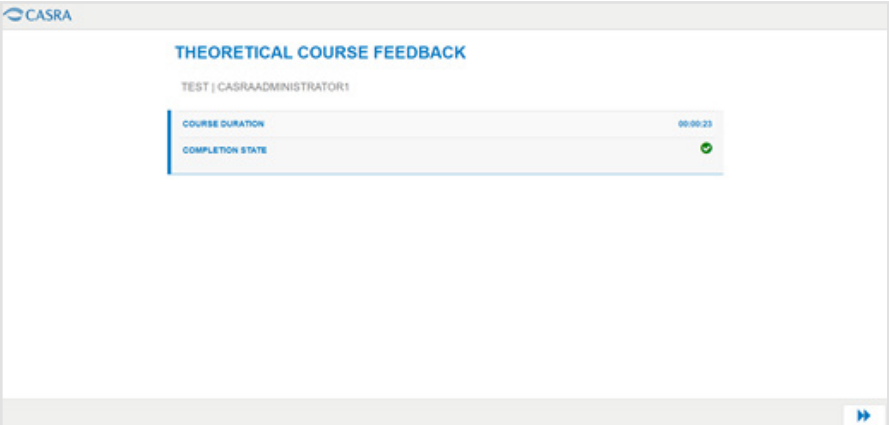

Figure 7: A customer can choose for each module to enable or disable feedback for theoretical courses

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