SCIENCE & SECURITY Issue 35

CASRA NEWSLETTER

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

The first article in this issue presents the findings of our study on 3D versus 2D imaging with 51 professional hold baggage screeners. The results show that, compared with 2D dual-view imaging of the same image quality, 3D imaging improves detection performance.

The second article presents CASRA's realistic browser-based 3D screening simulations integrated into the X-Ray Tutor, developed in response to the increasing adoption of 3D Computed Tomography (CT) scanners at security checkpoints.

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

DETECTING BOMBS IN HOLD BAGGAGE: 3D IS BETTER THAN 2D WHEN IMAGE QUALITY IS THE SAME

In a study with professional hold baggage screeners, we compared 3D imaging with 2D dual-view imaging using the same image quality. The results showed that 3D imaging improved bomb detection performance substantially, which is particularly important when bag images are more complex. The study provides strong evidence that 3D hold baggage screening improves human-machine system performance.

SECURITY IN PRACTICE

X-RAY 3D CT SIMULATORS

In recent years the use of 3D Computed Tomography (CT) scanners at security checkpoints has increased significantly. They are praised for increasing efficiency as well as the comfort of passengers [1]. With all of those new CT systems being introduced, operators need to be trained to make use of all the new features that 3D screening offers them. As providers of an all-in-one training and certification platform X-Ray Tutor (XRT), CASRA implemented simulations of such new screening procedures and brought them to the web browser. This enables operators to train in a highly realistic, simulated environment, without the need to install any additional software.

DETECTING BOMBS IN HOLD BAGGAGE: 3D IS BETTER THAN 2D WHEN IMAGE QUALITY IS THE SAME

Text: Marius Latscha and Adrian Schwaninger

In a study with 51 professional hold baggage screeners [1], we compared 3D imaging with 2D dual-view imaging under a key condition: image quality was kept the same in both modes. The results showed that 3D imaging improved bomb detection performance substantially, which is particularly important when bag images are more complex. The study provides strong evidence that 3D hold baggage screening improves human-machine system performance.

KEY FINDINGS

- 3D imaging improves visual inspection in HBS when compared with 2D Imaging of the same image quality.
- The advantage is visible in higher detection performance, and it is especially relevant for difficult, high-complexity bags.
- Although 3D inspection can take longer, 3D HBS is still more efficient than 2D HBS due to the lower false alarm rate of 3D HBS Systems.

INTRODUCTION

In hold baggage screening (HBS), automated explosives detection first flag suspicious areas, and human screeners then inspect the alarmed bags. The question of this study was highly practical: does 3D imaging help screeners make better decisions once a bag has been alarmed compared to 2D imaging of the same image quality? Earlier work suggested that the benefits of 3D could be reduced when image quality in 3D was poorer than in 2D [2]. The new study compared 2D and 3D under equal image-quality [1].

METHOD

The experiment involved 51 professional hold baggage screeners working with highly realistic X-Ray Tutor (XRT) simulators (Figure 1). Participants were randomly assigned either to a 2D dual-view condition or to a 3D condition. The 3D interface allowed image rotation and slicing, while the 2D interface showed the same bags from two fixed angles. Importantly, both conditions used the same underlying image set with identical image quality.

The task included 256 hold baggage images. Half contained an IED and half were target absent (i.e., contained no prohibited article). Bags were also classified as low or high in bag complexity, depending on clutter, opacity and the number of items present. This made it possible to test whether 3D imaging becomes especially useful when visual inspection is more demanding.

RESULTS

3D improved detection performance substantially (Figure 2). Screeners tested with 3D were better at correctly identifying bags containing an IED. Sensitivity measures from signal detection showed a clear advantage for 3D compared to 2D, confirming that the finding

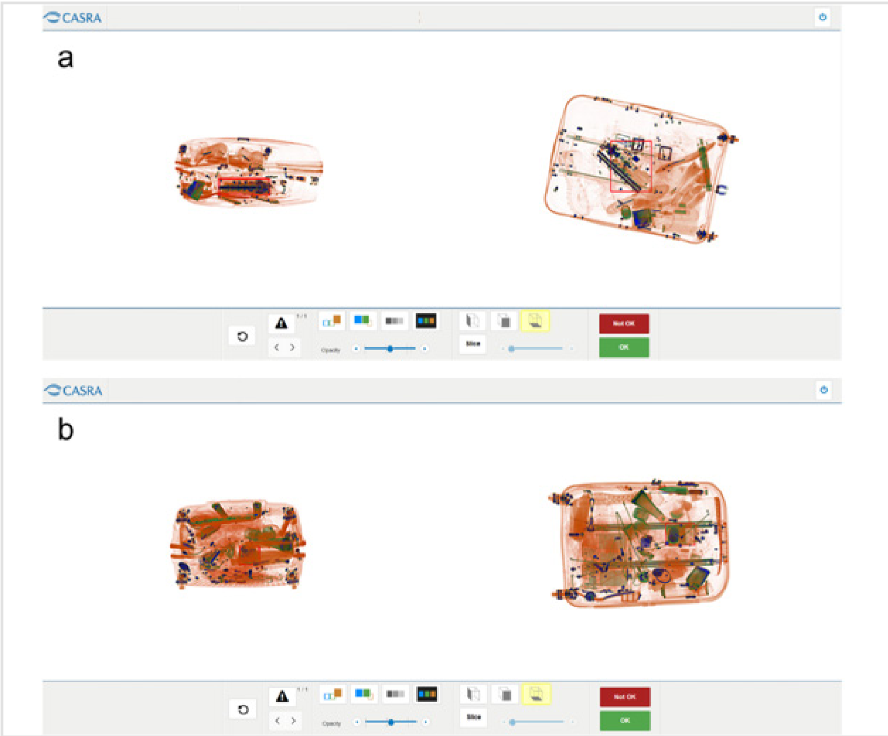

Figure 1: XRT simulator interface with (a) low complexity and (b) high complexity hold baggage images. In the 2D condition, the images appeared as static ducal views. In the 3D condition, the image on the left could be rotated in three dimensions and the image on the right could be sliced. [1]

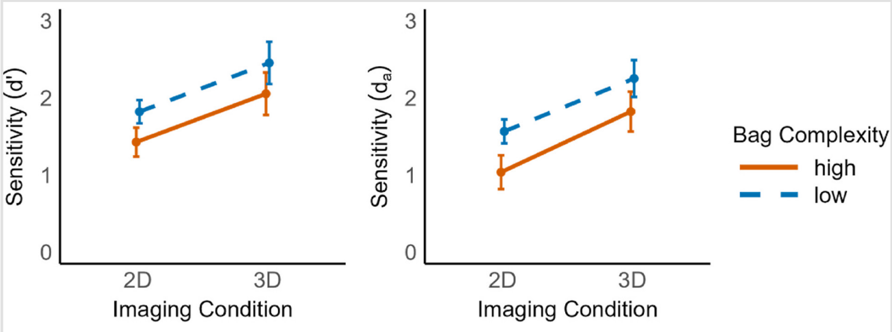

Figure 2: Detection performance in terms of sensitivity d' (left) and da (right) by imaging condition (2D, 3D) and bag complexity (low, high). Error bars represent 95% confidence intervals. From [1].

was not simply the result of a more liberal decision tendency. Bag complexity also mattered. Detection performance was better for low complexity bags than for high-complexity bags in both conditions. The gain from 3D was especially valuable for high-complexity bags. In other words, when the visual challenge increased because of clutter and overlapping objects, 3D rotation and slicing helped screeners more.

False alarm rate did not differ significantly between 2D and 3D. This is operationally important because false alarms have a negative impact on screening efficiency. The benefits of 3D did come with some increase in response time (Figure 3). On average, screeners spent longer inspecting bags in 3D than in 2D, which is plausible because rotation and slicing require active exploration of the image. Yet the time cost was limited. Target-present response times were only slightly higher in 3D and not significantly different from 2D. The main statistically significant difference appeared for target-absent bags with high complexity. The study suggests that the extra time invested in 3D mainly reflects more thorough inspection of difficult bags rather than a general slowdown across all screening decisions. However, it should be noted that 3D HBS is still more efficient than 2D HBS, because 3D HBS systems have lower false alarm rates than 2D HBS systems [1, 2].

DISCUSSION

The participating screeners had extensive experience with 2D screening but no prior operational experience with 3D HBS. Even so, they already performed better in the 3D condition after only limited familiarization. This indicates that the transition to 3D can generate measurable benefits early on, and that these benefits may become even stronger once screeners gain more 3D-specific training and practical experience. For airports still using 2D hold baggage screening, the findings support investment in newer 3D systems when image quality is adequate. For airports that have already transitioned to 3D in line with European requirements, the study reinforces the benefit of rotation and slicing available with 3D systems, especially when inspecting highly cluttered bags.

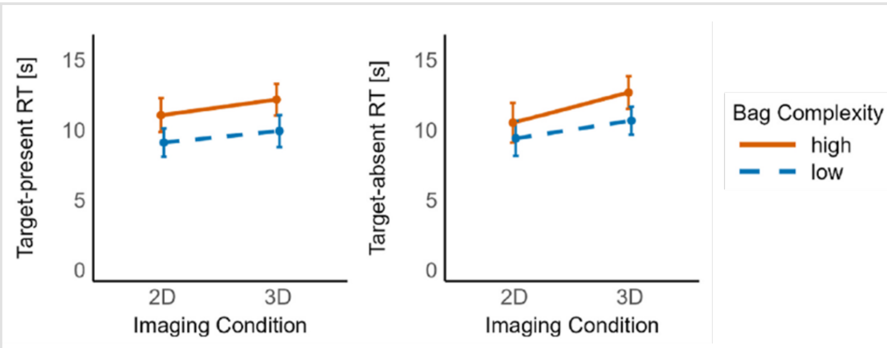

Figure 3: Target-present response time, and target absent response time by imaging condition (2D, 3D) and bag complexity (low, high). Error bars represent 95% confidence intervals. [1]

CONCLUSION

This study provides clear evidence that 3D imaging improves visual inspection in HBS when compared with 2D imaging of the same image quality. The advantage is visible in higher detection performance, and it is especially relevant for difficult, high-complexity bags. Although 3D inspection can take longer, 3D HBS is still more efficient than 2D HBS due to the lower false alarm rate of 3D HBS systems compared to 2D HBS systems. Overall, the study shows that 3D imaging is not only a technological upgrade, but also a meaningful improvement for HBS.

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[1] Latscha, M., Merks, S., Sauer, J., & Schwaninger, A. (2025). Detecting bombs in hold baggage: 3D imaging is better than 2D imaging when image quality is the same. *Applied Ergonomics, 128, 104534.*

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X-RAY 3D CT SIMULATORS

Text: Manuel Lippuner and Dominik Werner

In recent years the use of 3D Computed Tomography (CT) scanners at security checkpoints has increased significantly. They are praised for increasing efficiency as well as the comfort of passengers [1]. With all of those new CT systems being introduced, operators need to be trained to make use of all the new features that 3D screening offers them. As providers of an all-in-one training and certification platform X-Ray Tutor (XRT), CASRA implemented simulations of such new screening procedures and brought them to the web browser. This enables operators to train in a highly realistic, simulated environment, without the need to install any additional software.

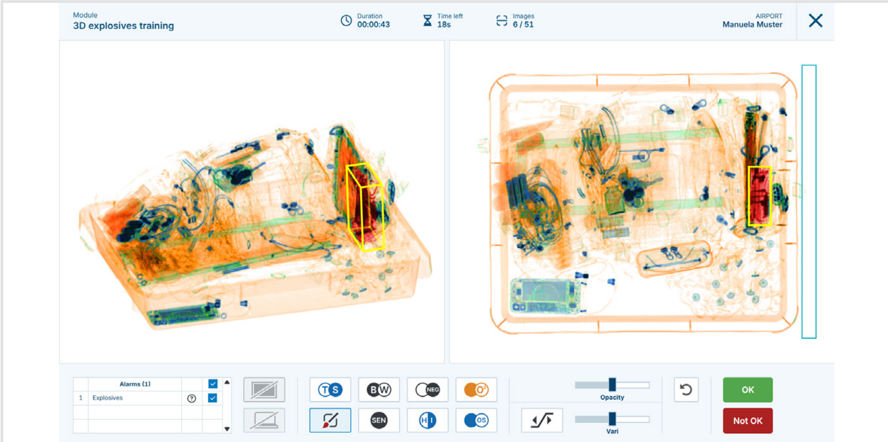

Figure 2: Active training session

There is great variety in the types of CT scanners that are available for security screening. They vary not only in their user interfaces (i.e. button placement, peripheral control) but also in the features they support and the rendering of the CT point clouds. Some features that are shared but implemented differently per scanner are listed:

COLOR REPRESENTATION

Each scanner interface represents the captured point clouds in a different way. It is up to the manufacturer to decide what the color and opacity of a material should be when it is shown on screen (see Figure 3).

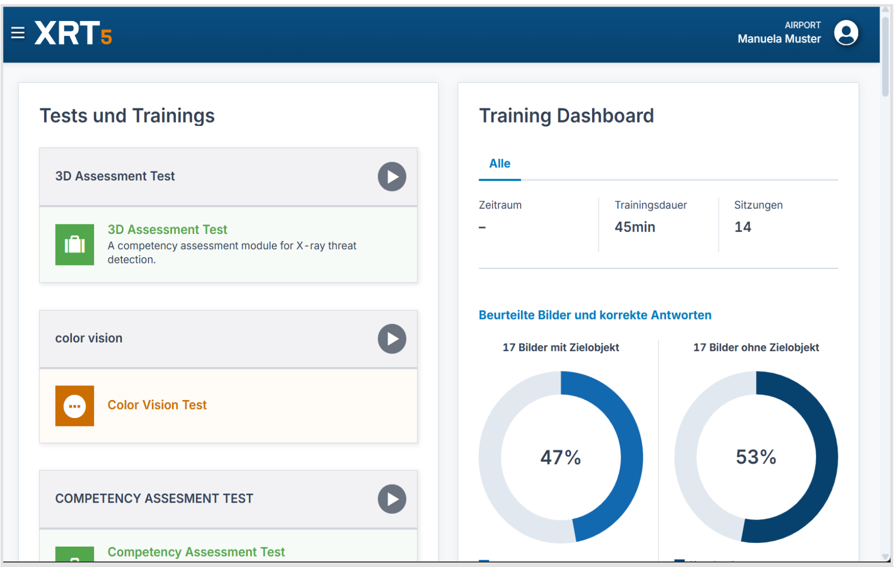

Figure 1: Landing page in XRT (X-Ray Tutor)

SLICING / ALARM ISOLATION

Captured CT images are a stack of two-dimensional X-ray images called slices. Many CT scanner interfaces allow operators to look at a smaller range of slices. This reduces the clutter and allows operators to look at certain parts of the image more closely (see Figure 4). Additionally, certain scanner interfaces allow to look at regions of interest in isolation (see Figure 5). Some even allow operators to draw their own regions that can then be isolated.

ALARM REPRESENTATION

There are automated detection systems that are active on CT scanners which can detect potentially dangerous objects. The interface then renders those regions in a different color to alert the operator (see Figure 6).

2D POST PROCESSING

Many CT scanners include post-processing tools similar to those used in professional image editing software. Different manufacturers implement different enhancements, for example edge enhancements (see Figure 7) or brightness and contrast sliders. These

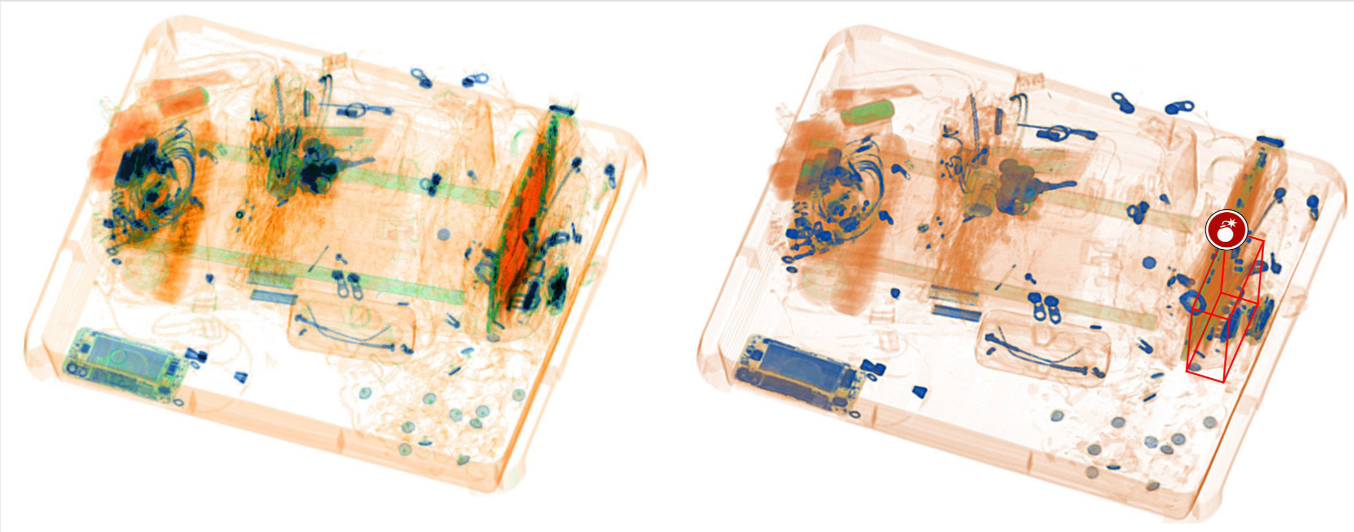

Figure 3: The same scan presented by two different simulators

enhancements are applied on top of the already rendered 3D output and are therefore operating on two-dimensional images.

All the listed features and more have been implemented in the scanner simulators that CASRA provides. Each scanner interface that was added to the simulator catalog posed its own set of challenges on different levels.

At the most basic level there is the challenge of rendering 3D graphics in the web browser in real time. This means that our software team has to be familiar with technologies like WebGL.

Even when the scanner specific render pipeline can be simulated in our application, the work is far from done: next, we need to setup the color and opacity transfer functions to match the render output of the real scanner interface. This process varies from scanner to scanner. In some instances we have the scanners in-house and we can access the interface directly. At other times we get emulators from the scanner manufacturers that we can use to optimize our representation. In some cases, we travel to customers to see the scanners in action.

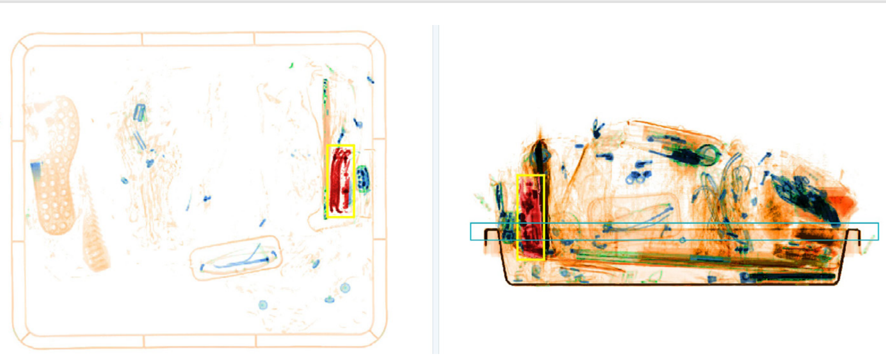

Figure 4: On the left viewport the sliced volume is displayed. The sliced region is controlled with the blue rectangle on the right viewport.

Another big challenge was adding support for the 2D post processing. The WebGL package we were using did not support those features. Our software engineers implemented this change to the render-pipeline from scratch and made a contribution to the original open source package so it can now be used by anyone.

Before being able to show anything during the training, we first have to import and process CT images recevied from many different sources (e.g. partner airports). While we support newer standards like DICOS, we also have a range of different formats that our team of X-ray imaging experts can work with. The need to work with so many different sources means that our 3D contents are vendor agnostic and can be used on any scanner simulator regardless of its origin.

Addressing all the software and computer graphics challenges led to the

Figure 5: Isolated region of interest.

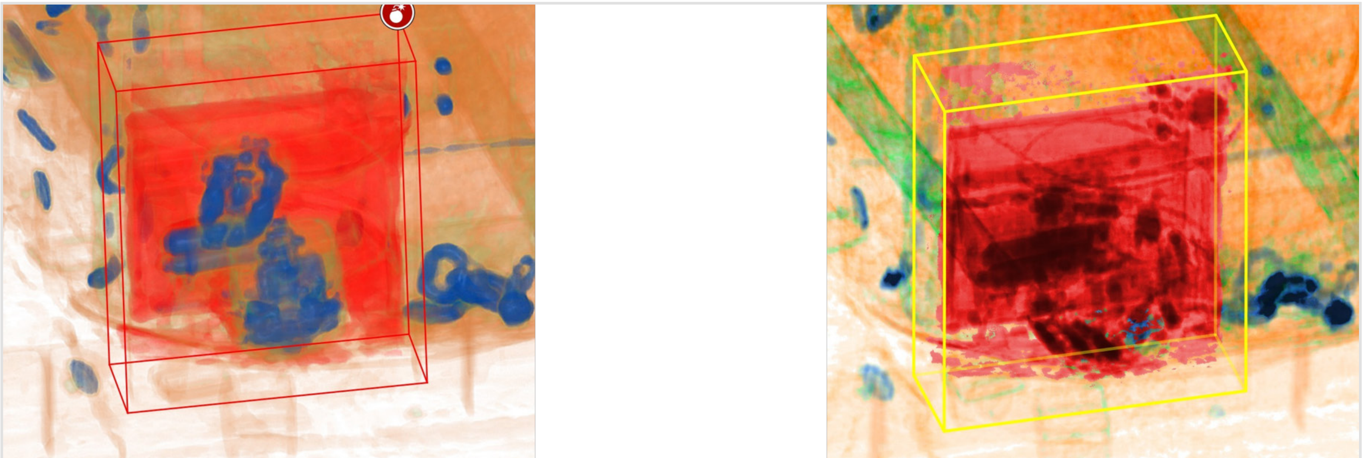

Figure 6: The same alarm coloring shown in two different CT scanner simulators.

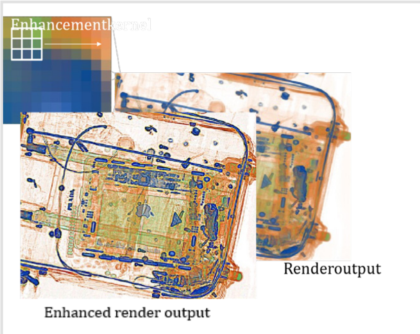

Figure 7: Illustration of a 2D edge enhancement kernel being applied to the output of the CT render pipeline.

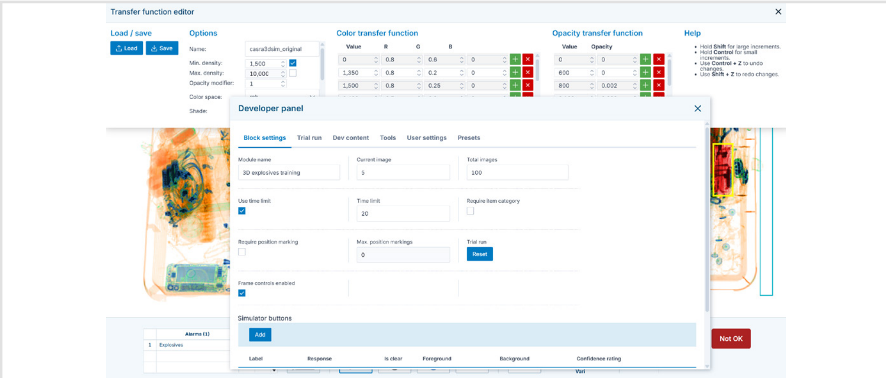

Figure 8: The developer mode used by engineers to work on simulator features.

creation of CASRA's own in-house 3D simulation framework. Whenever a specific problem needed to be solved a new component was added that can then be plugged into any simulator. The modularity means that new scanner interfaces can be added within a reasonable time frame if they rely on features that already exist in the catalog. Furthermore, the framework provides developer tools that allow our software engineers to focus their attention while working on specific features (see Figure 8). In some cases we even have multiple solutions to solve a problem, for example the alarm coloring. The framework supports a Central Processing Unit (CPU) bound solution that directly manipulates the point cloud

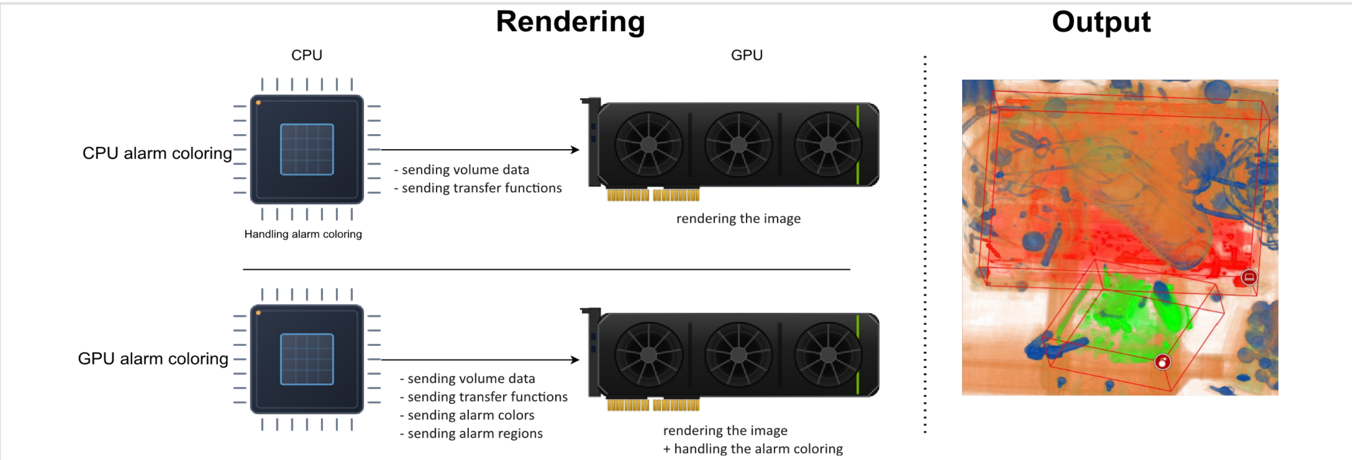

Figure 9: Two different methods for rendering alarm colors in CT images.

before it is sent to the Graphics Processing Unit (GPU) for rendering. The second method implements the logic fully on the GPU and the CPU only provides parameters to enable the region-based effects for alarm coloring (see Figure 9).

In conclusion, what makes CASRA's simulation platform so powerful is that the foundation was built iteratively. Components like the viewport were prototyped and reimplemented several times. Scanner features were analyzed and treated as independent components. Each new simulator adds more components to the overall framework. With these powerful tools, CASRA is well positioned to not only build high quality CT scanner simulators but also collaborate closely with the customer and iterate quickly on feedback. Through its modular 3D simulation framework, CASRA enables scalable training and certification for scanner operators.

CLOSE COOPERATION

There is always close collaboration between our software, research, content and threat assessment teams to build the best possible training and certification platform for X-ray screening. Based on all the collective knowhow, our upcoming generic 3D simulator will provide many of the common features seen in real scanners and integrate them in a way that makes it suitable for customers that use systems from multiple manufacturers. The aim in this case is to provide image interpretation training first without vendor specific workflows. For more information, reach out to our sales team: customerrelations@casra.ch

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