RESEARCH ON ADVANCED DISPLAY SYSTEMS FOR SECURITY EQUIPMENT

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BACKGROUND

Checkpoint airport security screeners across the country are provided with equipment to thwart counterattacks to our traveling public with the goal of causing fear, disruption of our daily life processes, and chaos to our economy. This equipment are their "extra-sensory tools" used to detect weapons and other threat items. Currently, handwands and metal detectors use electromagnetic fields to detect metallic objects that could potentially pose a threat. Explosive Trace Detectors use Ion Mass Spectrometry to detect for minute particles of explosives on people and their belongings such as laptops, shoes, and clothing. Cabinet X-ray machines generate X-rays for screeners to see through baggage to stop hidden threat objects from being carried past the checkpoint. These X-ray machines however, produce a planar image or a 2D representation of bags that usually contain layers of items packed on top of one another. It is the combination of these tools and the operators that use them that make up a major component of our security program.

Multiple cognitive processes (e.g., memory, pattern recognition, decision making, etc.) are required for the search task of scanning passenger baggage. When scanning bags, screeners must interpret their content within a 5 to 10 second timeframe, ensuring that items, which could cause serious harm are not carried past the security checkpoint and taken on board an aircraft.

These X-ray machines provide both color and monochrome displays with a number of other image enhancement features (i.e., magnification, high penetration X-ray, organic and inorganic stripping, etc.). Screeners view the two-dimensional (2D) representation of bag content to interpret the objects by what is displayed in their shape and spatial relationship to help them determine what is safe and what may pose a threat.

The acceleration of image processing and display techniques has allowed various manufacturers to develop enhanced display systems through software development, improved detector hardware, and modified X-ray generators thus increasing the resolution capability for image processing and rendering. Three-dimensional (3D) stereoscopic X-ray is just one example of the advancement of image processing for rendering scanned images in a different approach.

ADS Equipment

An Advanced Display System (ADS) is a display type which renders a sophisticated display image (i.e., 3D imaging) other than the 2D images currently displayed on flat screen monitors. 3D displays can be classified into one of four types: stereoscopic, volumetric, and holographic, motion 3D.

The AXIS-3D® is an example of an ADS which is a stereoscopic X-ray imaging system that enables operators to view 3D images of scanned baggage. The current generation of the stereoscopic 3D images produced by the AXIS-3D® system is analogous to how the human brain generates depth information from the differing viewpoints of the eye, thus benefiting the use of binocular cues. The AXIS-3D® X-ray camera detectors generate two slightly different angled, X-ray images of the objects being scanned presenting a separate image for each of the user's eyes. One method to ensure that each eye views the correct image is to use a polarizing eyewear in conjunction with an LCD filter which is attached to the computer display, thus presenting stereoscopic depth information about the bag and its content.

Synthosys is the developer of a stereoscopic projection display called the Synthosys 4D workstation. This ADS system projects 2 images of an object or scene onto a patented concave mirror. With the use of special graphics software, the images are merged in front of the observer to give the illusion that the image is floating in thin air.

The Lightspace DepthCube, a 3D volumetric display, uses 20 liquid crystal projection screens, each about 5 millimeters apart, where a sliced image of an object or scene is render on each screen, thus, when the images are combined, a volumetric display is created possessing both vertical and horizontal motion parallax. The DepthCube's 3D images are translucent and visible over a wide and continuous field of view and have all of the depth cues of real (3D) objects.

Actuality System produces a holographic-like display creating a 360° all encompassing view - without goggles. The Perspecta Spatial 3D System includes a 20-inch dome displaying full-color and -motion images that occupy a volume in space, giving users a view from any angle. Perspecta is a "plug-and-play" system, rendering all movement from an array of widely used open-standard 3D applications.

Past Research

In April of 2000, the Transportation Security Laboratory (TSL) conducted a study comparing screeners' threat detection performance using the AXIS-3D versus the conventional 2D X-ray (Barrientos, Dixon, and Snyder, 2000). The AXIS-3D X-ray machine manufactured by Image Scan Holdings of the United Kingdom (UK) was the ADS under evaluation. This was the company's first prototype stereoscopic X-ray machine and the first X-ray machine of its kind. During the study, screeners were tasked to find threats in bags using a conventional X-ray and the AXIS-3D. The results demonstrated that screeners' detection performance did not differ between the two image display formats; however, their false alarm rates were lowered, 6%, when using the AXIS-3D X-ray machine, implying that they were better able to identify non-threat objects and understand their spatial position relative to one another. Response times were longer using the AXIS-3D which can be attributed to the inexperience on the machine and that observers of the system had more information to view.

Recent Research

A test and evaluation was conducted in May 2004 at the TSL with a fluroroscopic X-ray machine, the Isorad SDS-400S, using TSA screeners (Klock, 2004). This machine is currently employed by El-Al, an Israeli airline, as their secondary screening method. The system uses dynamic motion, rotation of objects (i.e., passenger's baggage), to create a virtual 3D display on its high-resolution screen. Screeners' detection performance at finding artfully concealed threats such as Improvised Explosive Devices was compared using the Isorad SDS-400S machine versus a conventional X-ray machine – a single plane (2D), dual-energy X-ray system. Screeners performance was significantly better on the 3D system; however, their average response times per bag was 28 seconds while their average response times on the 2D system was approximately 10 seconds.

Two evaluations were conducted at Rampton Maximum Security Prison and East Midlands Airport in the United Kingdom in the summer of 2004 (Browson, 2004). The Rampton Study evaluated 16 highly experienced screeners (approximately 30.5 months on the job) using emulators of the actual display system for 3D and 2D. Screeners observed randomized images of the same 300 test bags on each display condition. The 300 test bag images included 50 bag images containing a threat.

The Rampton Study 16 highly experienced screeners (approximately 30.5 months on the job) as test participants using emulators of the actual display system for 3D and 2D. Screeners observed randomized images of the same 300 test bags on each display condition. The 300 test bag images included 50 bag images containing a threat. No significant differences between 3D (the Axis 3D) and 2D imaging formats were found for P_d, P_{fa}, or d'. The research team (Gibb, 2004) maintained that potential flaws to the test conducted can be attributed to the: 1) use of a particularly experienced test group where performance on 2D systems was uncharacteristically high, 2) use of emulators that may not have accurately mimicked either one or both of the two systems of interest, 3) possibility that stereoscopic imaging may benefit some screeners while having only limited impact on highly experienced screeners, and 4) restriction of time to view the images (approximately 8 seconds per bag image).

The East Midland Airport Study on the Axis 3D was conducted by the Centre of Human Sciences Division of QinetiQ of the U.K. QinetiQ also evaluated 16 airport security screeners' performance on the 3D and 2D display conditions using emulators to render 200 bags of which 50 contained threats (65% IEDs, 25% Guns, and 10% Knives). Screeners were limited to 8 seconds per image to observe and make a determination as to whether or not the image contained a threat or not. However, the results of this study have not be released to the TSA.

A recent study was conducted at San Francisco International Airport from October 18th to the 22nd, 2004 in which 16 TSA certified screeners from the Cendent Security Company were the test participants (Barrientos, 2005). The study was conducted in two parts: 1) Threat Detection Performance, and 2) Object Recognition. For Part 1, each test participant screened a total of 500 carry-on passenger bags (250 bags on 3D and 250 on 2D). For Part 2, screeners were asked to observe 2 sets of boxes on each display condition. Their task was to call out as many recognizable objects as possible within a 3-minute period. All screeners were given training on the ADS machine prior to the commencement of the study. Data collectors recorded screener responses (threat or clear), threat objects perceived for suspected bags, and bag response times. Both P_d and d' performance results were significantly different across technologies, an increase of 9% using 3D. The response times of screeners were longer using the 3D system which can be attributed to several factors: 1) inexperience with a new system 2) more information to observe, and/or 3) the Hawthorne Effect (knowledge of being tested). There was no difference in performance for the Object Recognition Test across display conditions.

DISCUSSION

ADS technology for X-ray imaging is an emerging technology and consequently only limited test and evaluation efforts are available to determine their effectiveness. Only recently have such systems matured to a level where controlled studies are possible. Few systems are available at a production model level to withstand the rigors of formal evaluation using thousands of test bags. Consequently it is extremely difficult to pool data from various test trials. In addition, such efforts require considerable investments as a result of the need to use experienced screening personnel and sufficient numbers of test bags or images to accurately assess threat detection performance. Accordingly such evaluation efforts typically use small test populations.

It is fortunate that previous studies have investigated the potential benefits of 3D stereoscopic 3D motion imaging technology. The first prototype system was evaluated five years ago (Barrientos, Dixon, and Snyder, 2000). Although not indicating a significant difference in P_d from conventional 2D imaging in the 2000 study, it determined that false alarm rates were significantly lower with stereoscopic imaging. The system under evaluation; however, was at an early stage of development, a first of its kind, and has since undergone substantial changes based on recommendations provided by the Transportation Security Laboratory (TSL). However, the most recent studies indicate improvements to screener threat detection performance with ADS equipment.

CONCLUSION

Given the current tools that TSA airport security screeners use, little (if any) improvement(s) can be made to detection performance using a planar view X-ray machine through training and performance measuring tools (i.e., TIP). Unless the TSA move towards fully automating the detection capabilities to find threats at a very high reliability rate, screeners' detection performance will not improve significantly. The display system is one major aspect of the security equipment (i.e., X-ray scanning machines) that can possibly improve screeners' ability to determine what are threats and what are non-threats. The results of studies show promise with ADS systems, which is an indicator to the TSA that further research be applied and investigated to this area.

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