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Future Small Arms Research (FSAR) Work Breakdown Element (WBE) 1.2.1 panoramic image capture

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Abstract

We presented technical details of capturing high resolution, electro-optical images and subsequent image stitching to create a large Field-of-View (FOV) image.

Résumé

Nous avons présenté des détails techniques de saisir des images à haute résolution, optoélectroniques et les résultats de couture ces données pour créer une grande image de champ de vue.

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1 Background

In the context of Future Small Arms Research (FSAR) Project, Electro-Optics (EO) for sighting systems are being studied under Work Breakdown Element (WBE) 1.2.1 Advanced sensors, optics and displays. In order to answer the question if various spectral bands and image fusion provide target Detection, Recognition and Identification (DRI) advantages in the battlefield, we have been performing a series of image collection campaign at CFB Valcartier and these collected data were used for studies on both technological and Human Factor (HF) performance in cooperation with effort of WBE 1.3.2 Optimizing Weapon Mounted Situational Awareness Targeting Suites (WMSATS) for the human. Image data was sent to DRDC – Toronto Research Centre for HF experiments using human test subjects. So far, high resolution image data with finite Field-of-View (FOV) was presented to test subjects with the use of computer screens or micro-displays in DRI task experiments. This mimicked a view through a limited FOV or EO devices such as goggles and weapon sights. As FOV of human nature vision is much larger, it will be essential to include in future HF studies this large FOV factor, especially during the target search and detection phase.

Laboratory experiments have been carried out using the Virtual Immersive Soldier Simulator (VISS) with the use of synthetic images to examine soldier performance. The VISS test bed arms the test subject with a mock weapon equipped with a micro-display scope and immerses him/her in the Virtual Battle Space 2 simulation environment with images projected by three projectors on three large screens. The VISS weapon physically represents the weapons used by soldiers today, but can be augmented by simulating various capabilities in the micro-display scope. The effect of specific attributes on soldier performance can then be examined.

In 2017, we have examined the possibility of using real, high resolution images on VISS for HF target DRI experiments. Here is one possible concept of operation. First, test subjects will do target search and detection task by looking at the large FOV image on the VISS screens. As this is viewed with naked eyes, this image will be in visible band. Upon detection, test subject will look at the micro-display scope for target recognition and engagement. As the test subjects raise the weapon, VISS keeps track of the weapon aiming position. The image presented to test subject in the micro-display scope will be a dynamic image chip associated to live weapon aiming positions and the corresponding image chip will be displayed for viewing. This "image chip" can be visible image, intensifying image, or other EO images to simulate other capabilities. As it is a must to present an image chip with sufficient resolution and details, high resolution image of the entire FOV presented to test subjects is required. In this case, we can study HF performance beginning from the head-up search stage in a complete target DRI sequence.

This Reference Document describes technical specification, experiences and lessons learned during a first effort to collect high resolution image data and presents results of the fused, large FOV images.

2 Experimental procedure and specification

2.1 VISS

As the large FOV, high resolution images are projected onto the screens of VISS, it is required first to examine the specification of the VISS. Referring to Figure 1, the three screens are positioned next to each other with the two on the sides at an angle. The apparent total width for viewing is 7.84 m and height 1.47 m. A test subject will stand at 4 m from the screens. This makes an apparent FOV to the test subject at 89 by 20 deg. Therefore, the large images should fit within and provide such FOV to test subjects.

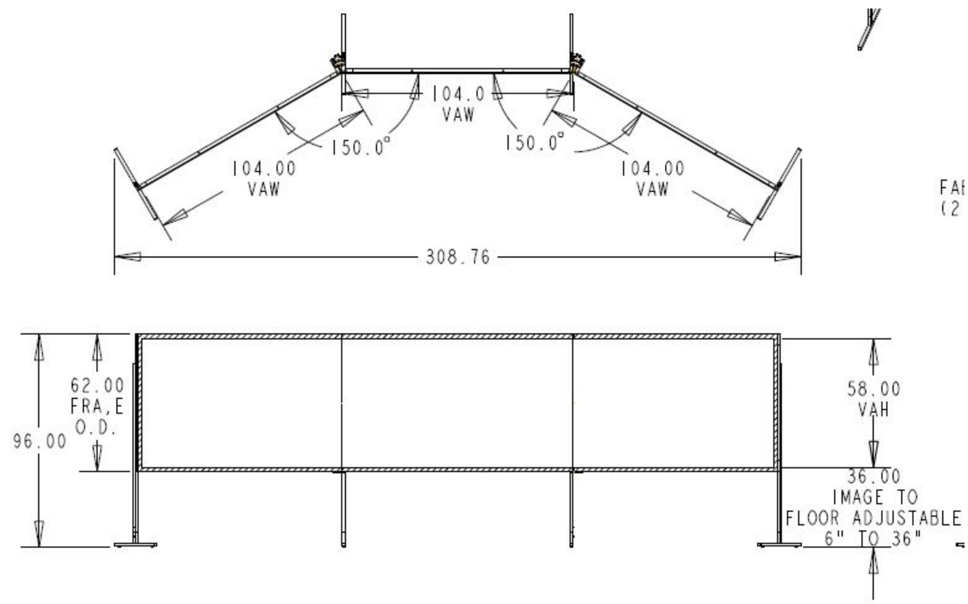

Figure 1: *Schematic of screen configuration of VISS (measurement indicated in inches).*

2.2 Cameras

A visible, a Shortwave Infrared (SWIR) and a Longwave Infrared (LWIR) were selected to capture image data which would then be fused to create a large FOV visible, SWIR and LWIR images. All three cameras capture images at high resolution with a finite FOV:

- Visible camera—Prosilica GC2450, 1224 by 1025 in resolution, 50 mm lens, 9.7 by 8.1 deg FOV (63 line pairs per deg),
- SWIR camera—Goodrich 1280JS, 1280 by 1024 in resolution, 100 mm lens, 9.2 by 7.3 deg FOV (70 line pairs per deg),
- LWIR camera—Custom made, 1024 by 768 in resolution, 100 mm lens, 10.0 by 7.5 deg FOV (51 line pairs per deg).

It is not possible to use large FOV lens on any cameras as this will degrade image resolution and details. The only possibility is to have the cameras capture multiple images across the entire FOV. A motorized, programmable pan-and-tilt stage was used.

2.3 Pan-and-tilt stage and pre-selected positions

The pan-and-tilt stage was made by Moog Inc. (was QuickSet Inc.). With the FOV coverage and those of cameras, pre-selected positions were determined according to the pan-and-tilt specification:

Model QPT-90 Marine

- Pan angle: ±210 deg from center,
- Pan speed range: 1 to 35 deg per second,
- Tilt range: ±90 deg,
- Tilt speed range: 1 to 12 deg per second,
- Repeatability: 0.25 deg,
- System dimension and weight: 318 mm x 253 mm x 461 mm, 9.3 kg,
- Control: RS232 via Window-based interface program, Store up to 32 different positions (azimuth and elevation),
- Load capacity: 90 lb-ft (122 Nm) maximum.

It is noted that it is required to have overlapping zone between adjacent images (left, right, above, bottom) to facilitate image stitching to create the final large FOV image. The 32-position limit of the pan-and-tilt stage poses a constraint of how much overlapping could be had within a programmable operation. Here is the design positions and scanning path to cover the 90 by 20 deg FOV (Figure 2).

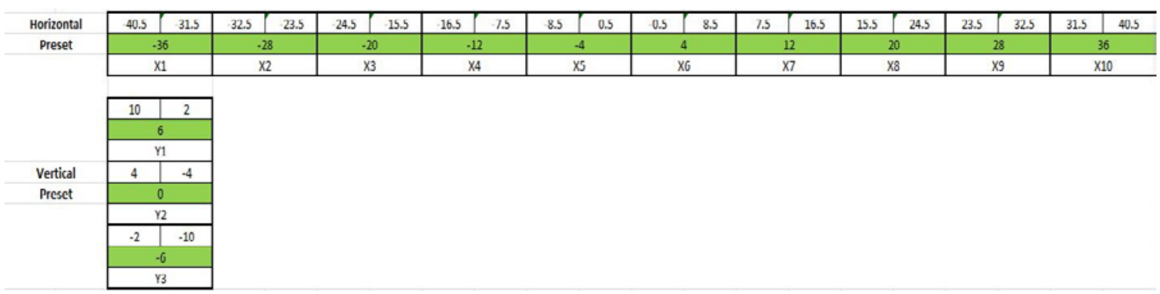

Figure 2: *Pre-selected azimuth and elevation positions.*

Ten horizontal positions (-36, -28, -20, -12, -4, 4, 12, 20, 28, 36 deg) along with three vertical positions (6, 0, -6 deg) were selected (shown in green boxes in Figure 2). Each horizontal position covers a minimum of 9 deg (4.5 and -45 deg) and vertical position a minimum of 7 deg (3 and -3 deg), which are within the maximum FOV of all three cameras. The pan-and-tilt angular movement along horizontal and vertical are 8 and 6 deg to obtain overlapping zone of adjacent images, which are 0.85, 0.56 and 1.00 deg horizontally and 1.05, 0.65 and 0.75 deg vertically for visible, SWIR and LWIR images. These are about 6 to 12% overlapping with respect to the captured images. The FOV of the final image is about 80 by 20 deg. A total of 30 positions which are under 32 are required. Larger overlapping zone will result in more positions to cover 90 by 20 deg FOV. The pan-and-tilt operation follows a Z-pattern, i.e., Begin; Left-to-right; Lower; Right-to-left; Lower; Left-to-right; End.

2.4 Operation

A dry run was performed on August 21, 2017 at Sector 3A of CFB Valcartier. The three cameras were mounted on the pan-and-tilt stage which was programmed to first perform a step-by-step pan-and-tilt to cover the 80 by 20 deg as described above. Before operation, the focus of all cameras were checked and adjusted with the use of a standoff E-letter target. When operation began, the cameras began taking images at 30 frames per second. Image output was stored in a computer. At each step, the stage stopped for one second before moving to the next step. This is to eliminate possible image blur. A continuous operation without stopping was performed as well to validate if image blur did cause problems. The operation duration and total image data size were slightly reduced in the latter. Figures 3 and 4 show the cameras, pan-and-tilt stage and a trailer deployed during the dry run.

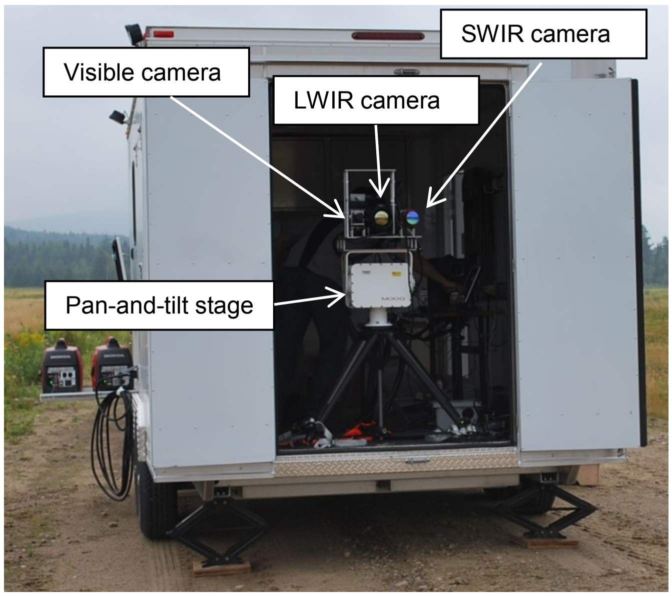

Figure 3: *Image showing cameras and pan-and-tilt stage inside a trailer.*

Figure 4: *Close-up view of the cameras, cables and the pan-and-tilt stage.*

3 Results and discussion

Visible, SWIR and LWIR image data was successfully captured on August 2017. This data was sent to DRDC – Toronto Research Centre for stitching and further enhancement such as cropping, gamma-adjustment and sharpening. Figure 5 shows an example of stitched SWIR image and Figure 6 an enhanced version.

Figure 5: *Final large FOV SWIR image insert showing close-up of the E-letter target.*

Figure 6: *Final large FOV SWIR image with enhancement with insert showing close-up of the E-letter target.*

Comments and several issues were noted as follow:

- The final image is about 11 500 by 2750 in resolution for FOV of 80 by 20 deg. This results in about 70 line pairs per deg which is the same as the resolution of original SWIR camera.
- The Depth of Focus (DOF) of the cameras is narrow. This led to out-of-focus in some parts of the final image, especially the top and bottom parts. This tends to draw the eye towards the horizon middle section where everything is in-focus. It may be acceptable if targets are positioned near and along the middle section of the image. If target search is required also outside the middle section, focus should be re-adjusted multiple times within an operation.
- An image stitching software tool was used to create the final FOV image. As a number of recognisable patterns in images are required to facilitate image stitching algorithm, difficulties emerged with images appeared out-of-focus. In Figures 5 and 6, for example, the bottom part with out-of-focus grass required several attempts and parameter adjustment.
- It was determined that an ideal overlapping zone is about 25 to 50% of the original image. It is possible to have less but it resulted in less robust image stitching operation. More than

50% overlapping means a blending contribution and subsequent adjustment from more than two images is required.

- If an overlapping zone is to increase to 25%, more positions than 32 will be required for one complete scan. An alternative is to first store and run through a scan with all azimuth data / horizontal positions at one elevation data / vertical position, then the follow up elevation data / vertical positions will be entered on site for the next two scans.
- It is not required to operate capture images during the entire scanning operation, which generated too much unnecessary data. A few captured images at each step are sufficient.
- This first effort had yet to stitch LWIR images. In general, as LWIR images contain less details (feature, texture, contrast) and are less sharp compared to visible and SWIR images, stitching process may be less robust, especially those out-of-focus images.
- Image collected by scanning without stopping did show image blur. A step-by-step strategy is preferred.

4 Conclusions

A dry run was performed to capture visible, SWIR and LWIR images of around 10 deg FOV over an 80 deg FOV scene with the use of a programmable pan-and-tilt stage. A large FOV, high resolution SWIR image was created by stitching multiple images. This high resolution, large FOV image may be integrated into VISS in future HF immersive experiments. Several issues and challenges were identified for further improvement.

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