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14. ABSTRACT
This report results from a contract tasking TNO Defence, Security and Safety as follows: The grantee will acquire and register a multimodal dynamic target image test set that can be used to assess the operational effectiveness of static and dynamic image fusion techniques for a range of relevant military tasks.
TNO originally developed the TOD (Triangle Orientation Detection) method to predict human target detection and identification performance from static imagery. The TOD method produces a TOD-curve that resembles an MTF or MRTD (commonly used to evaluate thermal sensors). However, the TOD-method is more directly related to the target recognition task, and is better suited at capturing nonlinear effects of the kind that typically occur in image fusion methods, such as sampling and (local) contrast enhancement. In the proposed project grantee collected dynamic nighttime and daytime imagery using sensors with various spectral sensitivities. The sensors were thermal, SWIR, NIR, and visible wavelength cameras that will be mounted on a common base plate. The sensor suite as a whole will be placed in a vehicle, allowing one to register approach sequences to the targets. The targets were military relevant targets such as personnel or, if possible, military vehicles. Included with each target sequence will also be triangles with a range of different sizes, thermal and visual contrasts. This will allow TOD-measurements (characterizing object recognition performance) on the resulting set of multimodal images that can be compared with human task performance using the same imagery.
At total of 16 runs were successfully registered, partly in dry and partly in rainy conditions. The imagery collected during this study, together with the GPS data and all other documentary material, was made available to the Air Force Research Laboratory organization at the end of the field trials. Researchers from both the Air Force Research Laboratory and TNO Human Factors will write a joint paper on (a) laboratory experiments that will be performed in both labs with the imagery that has been collected in the present study, and (b) on the way in which this can be further deployed for future laboratory experiments. This joint paper will be presented at the SPIE Defense, Security + Sensing Symposium in Orlando, Florida, 13-17April 2009.

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Registration of a Dynamic Multimodal Target Image Test Set for the Evaluation of Image Fusion Techniques

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Final Report

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1 INTRODUCTION

In this project we acquired and registered a multimodal dynamic target image test set that can be used to assess the operational effectiveness of static and dynamic image fusion techniques for a range of relevant military tasks.

The fusion of multimodality (multi-spectral) images and video sources is emerging as a vital technique for surveillance purposes, navigation and object tracking applications. The main goal of image fusion is to provide a single compact representation of the input images that is more informative than each of the individual inputs. There are several potential benefits of multi-sensor image fusion: wider spectral, spatial and temporal coverage, extended range of operation, decreased uncertainty, improved reliability and increased robustness of the system performance.

In many applications the human perception of the fused image is of fundamental importance. As a result, image fusion results are mostly evaluated by human visual inspection. Subjective evaluation tests are often time-consuming, expensive, impractical or even outright dangerous. Moreover, such methods often do not correlate well with how people perform in actual tasks utilizing fused images. This has led to an increasing demand for efficient and objective tests that allow rapid comparison of the results obtained with different algorithms, or the automatic selection of the appropriate fusion algorithm for a given scenario, or to obtain the optimal settings for a specific fusion algorithm.

Effective image fusion systems should provide a more complete representation (with increased information content) of the scene, which is easier to interpret and understand (ergonomic value). A range of different image fusion algorithms is currently available, many of which can be implemented in real-time. In practice many image fusion algorithms merely produce fused images with an increased amount of detail (compared to the original input images) without taking into account the information content (the meaning) of the resulting combined details. As a result, the perceptibility of relevant features in the fused representation of the scene may be degraded, and task performance may be adversely affected. For instance, when clutter is included in the fusion process a large number of spurious (i.e. non-informative or task irrelevant) details may appear in the resulting fused image. As a result human or machine performance of target detectability and target classification may be severely degraded.

Image quality is task related. A fused image can be said to be of good quality if it allows the observer to achieve a task performance that is similar to or better than the performance that can be achieved with the original, individual images. However, the quantification of this performance assessment is often difficult and time consuming. Hence, there is a need for efficient and reliable methods to quantify the operational effectiveness of image fusion systems.

The multimodal nightvision imagery collected in this study can and will be used to (1) evaluate existing image fusion schemes, (2) to design and optimize new dynamic image fusion schemes, and (3) to develop new image fusion quality metrics. In the next sections we will give a detailed account of the equipment, the scenario, the targets, the registration location, and the environmental conditions.

2 EQUIPMENT

An instrumented truck (see Figure 1b) was used to house the equipment (computers and monitors) that was used to register and monitor the imagery.

The sensor suite (see Figure 1b) was placed just outside the truck and consisted of

- A Lion Advance 8-12 micrometer longwave thermal camera (Thales Optronics), with a field-of-view of 7.8x5.9 degrees, a focal point distance of 81.71 mm, a detector pitch of 35 μ, and a NETD<80mK.

- A Raytheon Radiance High Speed, 256x256 pixels, InSb focal plane array midwave thermal camera (Raytheon).

- A digital image intensifier (DEP), with a field-of-view of 8.1x6.1 degrees.

The analog signals from all cameras were digitized using a Matrox MIL Lite framegrabber.

GPS signals were continuously registered both at the location of the sensor suite and at the location of the targets. During the experiment the soldiers carried a backpack with a laptop (Dell Inspirion) that was attached to a BU-353 USB SiRF Star III GPS receiver. An identical combination of GPS receiver and laptop was placed next to the sensor suite. The difference between these two GPS signals at a given time corresponds to the distance between the target and the sensor suite at that time.

(a)

(b)

Figure 1. Sensor suite (a) situated just outside the registration truck and (b) in close-up. Left: the Lion Advance 8-12 μm thermal camera; upper middle: the digital image intensifier; right: the Radiance HS 3-5 μm midwave camera.

3 SCENARIO

The scenario was as follows. A soldier, wearing standard camouflage clothing and carrying a target object, approached the sensor suite along a straight line, starting at a distance of approximately 300 m. When the soldier had neared the cameras to a distance of about 40 m the image collection stopped and he retuned along the same route to his starting position. Each time the soldier reached the starting point he exchanged the target object for another one. Then the image registration started again and the soldier walked at a steady pace towards the cameras. This procedure was repeated until all targets had been used once. All image registrations were done after dark. In these conditions, the targets were not visible with the naked eye for the largest part of the track (they could only be noticed at close range).

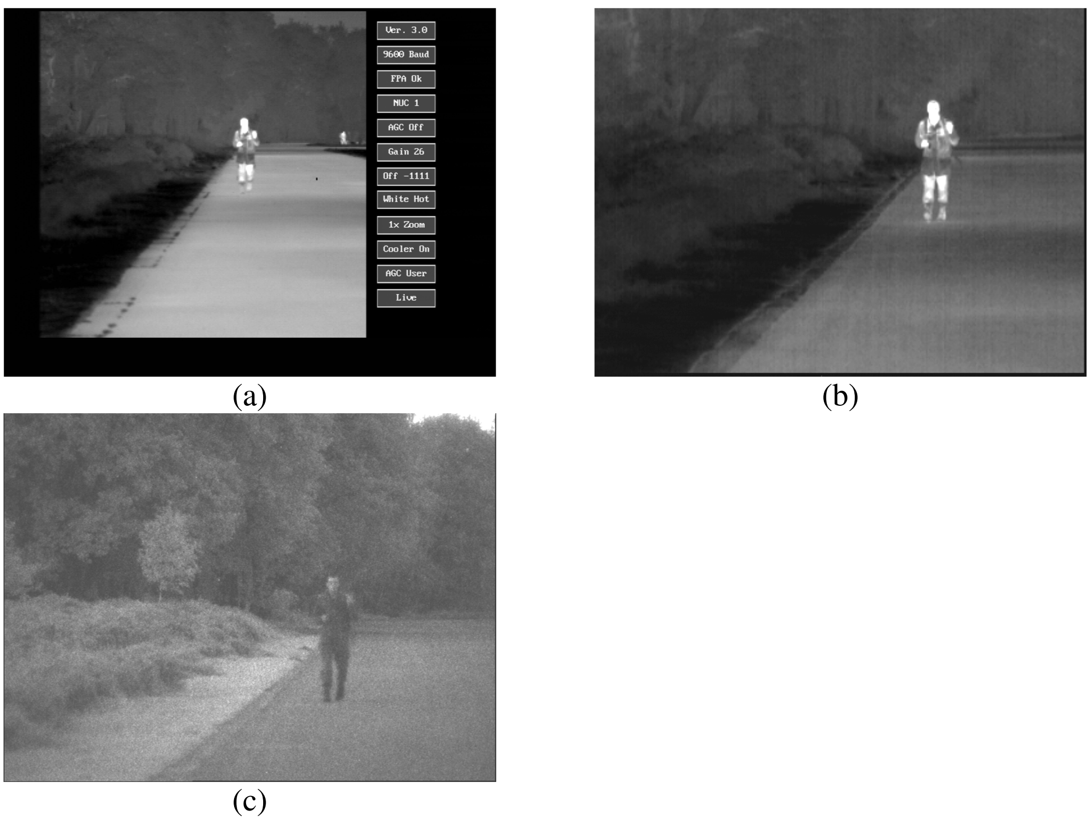


Figure 2. Corresponding images from an approach sequence, taken respectively with (a) the Radiance HS 3-5 µm midwave camera, (b) the Lion Advance 8-12 µm thermal camera, and (c) the digital image intensifier. The images show a soldier carrying a target object. The recordings were made in complete darkness, such that the target was not visible with the naked eye.

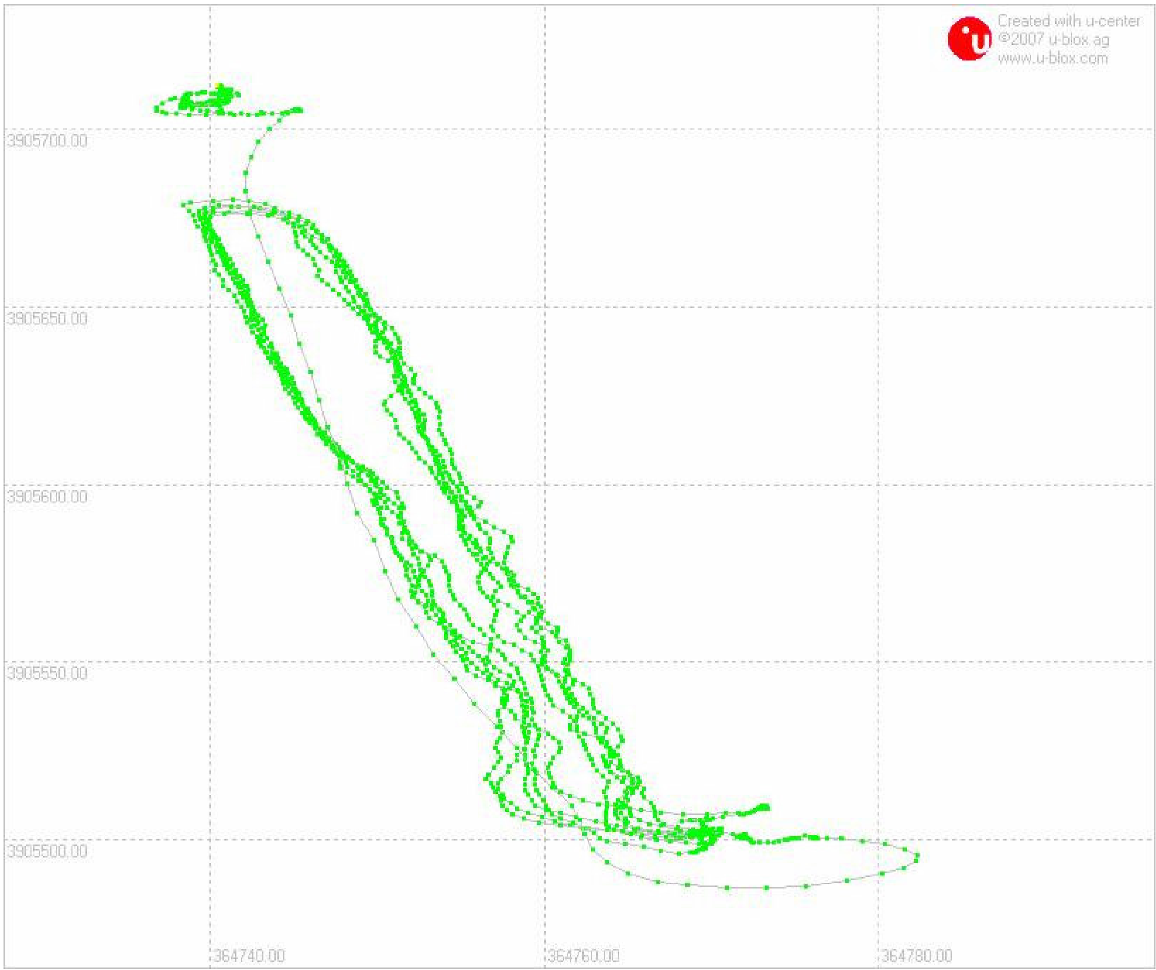


Figure 3. GPS tracks of soldiers approaching the cameras (lower direction) from afar (upper position) and turning around to their starting position.

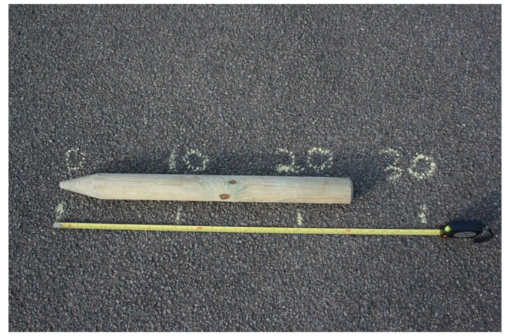
4 TARGETS

Figure 4 shows images of all the targets that were used in this experiment. The targets were respectively a wooden hammer, a wooden stake, an axe, a Mach machine gun, an M16, a Minime and a Glock handgun. Table 1 lists the characteristic dimensions (length and width) of all these targets.

Table 1. targets and their characteristic dimensions.

Target	**Length (cm)**	**Width (cm)**
Hammer	40	19
Stake	81	5
Axe	88	22
Mini SAW	91	-
M-16	40	26
M-60 light machine gun	126	-
Glock	18	13

(a)



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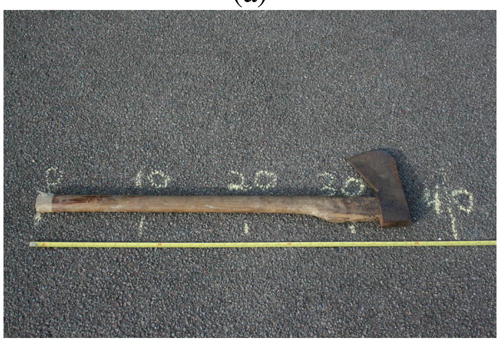
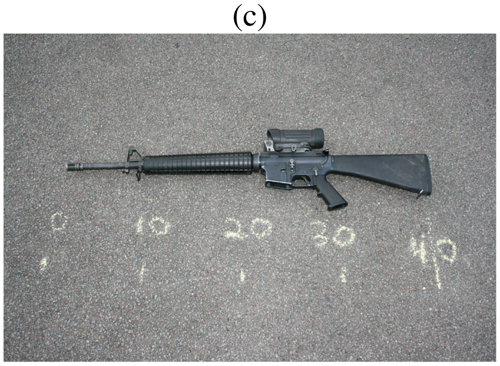
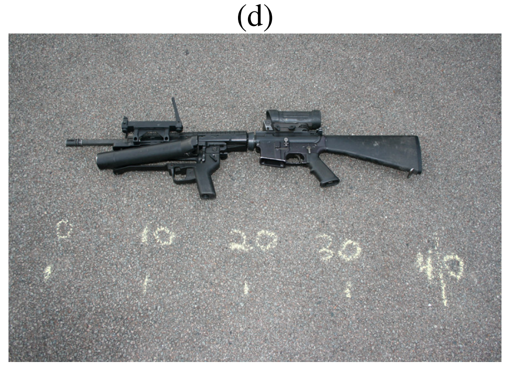


(c)

(d)

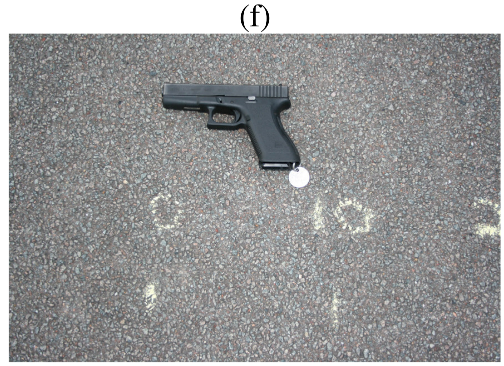


(e)



(f)

(g)



(h)

Figure 4. The targets: (a) hammer, (b) stake, (c) axe, (d) mini SAW, (e) M-16, (f) M-16 with grenade launcher, (g) M-60 light machine gun, (h) Glock.

5 REGISTRATION LOCATION

The Vlasakkers registration site was located on a military base in Amersfoort, The Netherlands. Figure 5 shows the registration location in daytime. The background consisted of a forest line. The terrain to the left of the track consisted of heather and grass, which provided a cluttered background. To the right of the track there was a tarmac road. The soldiers walked towards the camera standpoint from a distance of about 300 m (near the treeline in the back). Their path was near the edge of the road, just along the grass.

Figure 5. Registration location in daytime. During image registration at night soldiers approached the caneras from the distance, walking along the edge of the road near the grass.

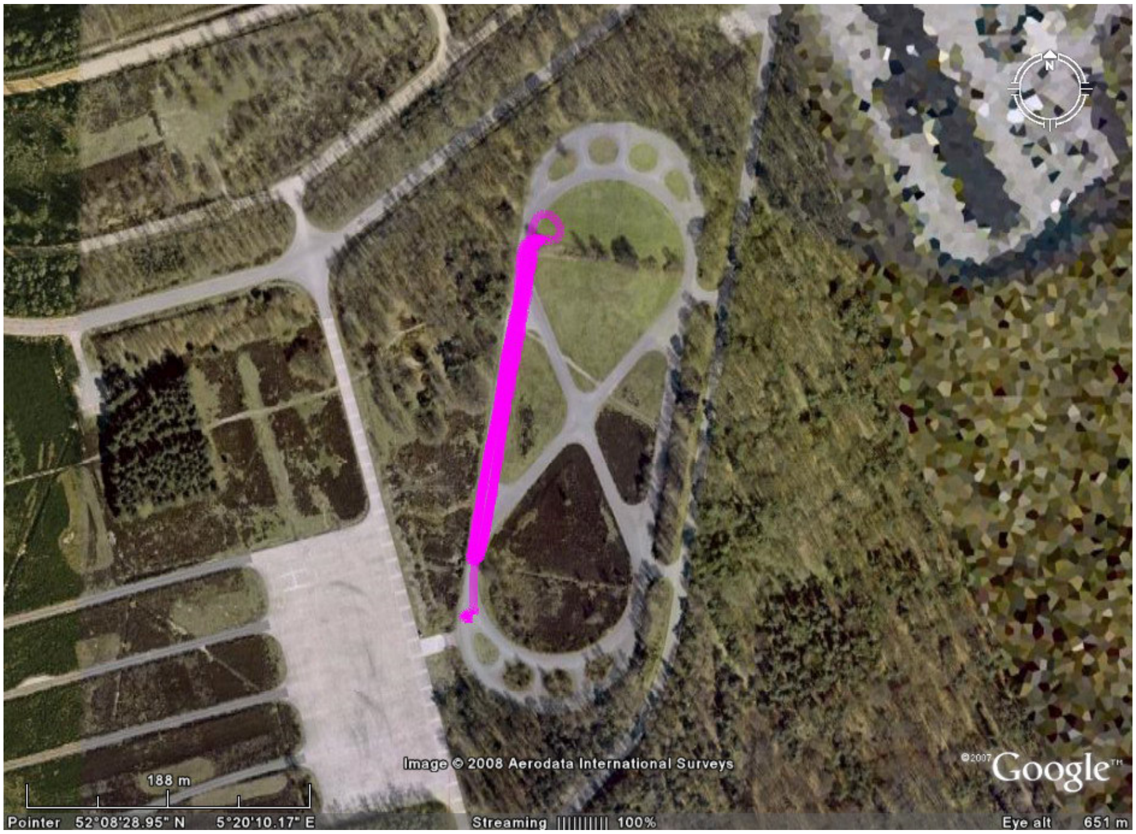


Figure 6. The GPS track data projected onto a Google Earth satellite view of the registration location.

6 ENVIRONMENTAL CONDITIONS

The image collection was performed during the night of Tuesday 9 September 2008. The weather was quite variable during the registration period.

At the start of the registration period it was dry and the visibility was good. After completing 5 consecutive runs it started to drizzle. The next 11 runs were performed during the rain. At the end of the experiment it was dry again. Table 2 lists the meteorological data at the time and location of the field trial.

Table 2. Weather data of Tuesday 9 September 2008 at de Bilt, near the registration site. Source: The Royal Dutch Meteorological Institute.

Weather data of tuesday 9 September 2008 at De Bilt					
Temperature		**Average**	**Precipitation**		
Mean	17.3 °C	15.2 °C	24h sum	2.9 mm	
Maximum	23.3 °C	20.0 °C	Duration	1.5 hours	
Minimum	10.0 °C	10.4 °C			
Sun, cloud cover & visibility			**Wind**		
Duration sunshine	10.1 hours		Mean	3.0 m/s	= 2 Bft
Relative sunshine duration	77 %	37 %	Maximum hourly mean	5.0 m/s	= 3 Bft
Average cloud cover	4 octa's partly cloudy		Maximum gust	11.0 m/s	
Minimum visibility	0.4 km		Prevailing direction	151 °	= SSE
Relative atmospheric humidity			**Air pressure**		
Mean	79 %	82 %	Mean air pressure	1014.1 hPa	

7 CONCLUDING REMARKS

At total of 16 runs were successfully registered, partly in dry and partly in rainy conditions.

The imagery collected during this study, together with the GPS data and all other documentary material, was made available to the Air Force Research Laboratory organization at the end of the field trials.

Researchers from both the Air Force Research Laboratory and TNO Human Factors will write a joint paper on (a) laboratory experiments that will be performed in both labs with the imagery that has been collected in the present study, and (b) on the way in which this can be further deployed for future laboratory experiments. This joint paper will be presented at the SPIE Defense, Security + Sensing Symposium in Orlando, Florida, 13-17 April 2009.