Using Satellite Imagery to Evaluate Land-based Camouflage Assets

J BAUMBACH, M LUBBE
CSIR Defence, Peace, Safety and security, PO Box 395, Pretoria, 0001, South Africa
Email: jbaumbac@csir.co.za

ABSTRACT
A camouflage field trial experiment was conducted. For the experiment several targets were deployed along tree lines and in an open field. Some of the vehicles were deployed with a variety of camouflage nets, while others were left uncovered. Unobstructed target panels were also deployed and served as calibration targets. During the trial, CSIR Defence, Peace, Safety and Security acquired both airborne and spaceborne (QuickBird, Spot 5 and Radarsat 1) imagery over the trial sites, and conducted extensive calibration and ground truthing activities in support of these acquisitions. This study further describes the processing that was done after acquisition of the datasets. The goal was to determine the best image processing techniques to use for effective camouflage detection.

INTRODUCTION
Detection of targets in remotely sensed data is a relatively difficult task. There are several reasons for this difficulty. Due to the size of the targets combined with the spatial resolution of the sensor, the information related to the target is usually contained in few or even one image pixel. The problem is further complicated when the spectral properties of the target are very similar to the ones of the surrounding background, thus making separation (identification) very difficult. Since in multispectral imagery each frame has large bandwidth associated with it, separation between the target and the background may not be easily detected, but can still be done as illustrated in this study using standard image processing techniques.

The purpose of the field trial was three-fold:
- To demonstrate the capabilities of commercial satellites
- To demonstrate the camouflage efficiency/inefficiency of the equipment used
- To demonstrate the capability of image exploitation techniques for camouflage detection work.

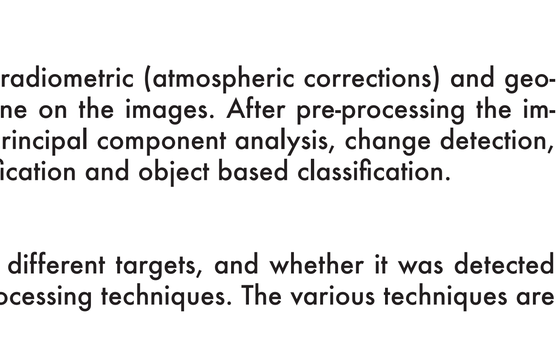
This was done by acquiring images of a typical deployment in the visual, near infra-red (VNIR) and radar wavelengths. Scientists within CSIR performed the assessment of the camouflage effectiveness against airborne and spaceborne sensors.

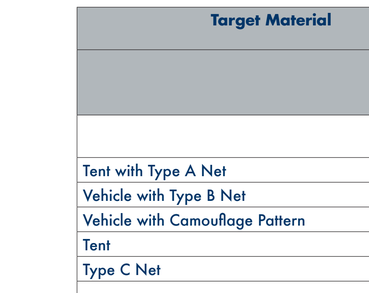
METHODOLOGY
During the image pre-processing phase both radiometric (atmospheric corrections) and geometric corrections (geo-referencing) were done on the images. After pre-processing the images were processed using image merging, principal component analysis, change detection, un-supervised classification, supervised classification and object based classification.

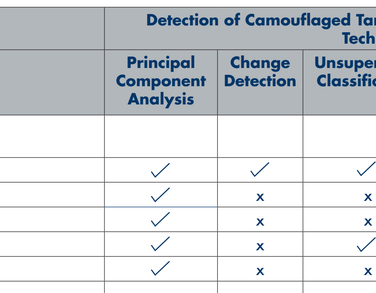
RESULTS
The following table shows a summary of the different targets, and whether it was detected (✓) or not detected (x), using the various processing techniques. The various techniques are discussed in the next section.

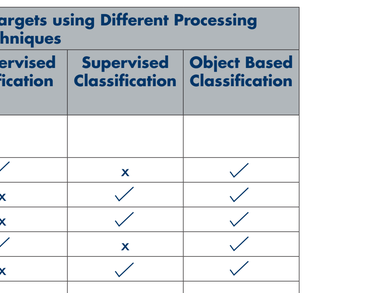
Target Material	Detection of Camouflaged Targets using Different Processing Techniques				
	Principal Component Analysis	Change Detection	Unsupervised Classification	Supervised Classification	Object Based Classification
Tent with Type A Net	✓	✓	✓	x	✓
Vehicle with Type B Net	✓	x	x	✓	✓
Vehicle with Camouflage Pattern	✓	x	x	✓	✓
Tent	✓	x	✓	x	✓
Type C Net	✓	x	x	✓	✓
Accuracy of detecting camouflaged targets – Selected Area Shown (%)	100%	20%	40%	60%	100%
Accuracy of detecting camouflaged targets – Whole Image (%)	67%	56%	40%	63%	100%
Overall accuracy of classifying all objects – Whole Image (%)	67%	56%	71%	85%	100%

DISCUSSION
The first image analyses technique used is called Principal Component Analyses (PCA). This technique looks at the different multispectral bands (also known as the principal components (PC)) of the image. The biggest advantage of this technique is that it removes redundancy in multispectral data [2]. During image analyses some camouflaged objects were extracted from the 3rd and 4th PC as an anomaly. The success rate of detecting camouflaged objects, using PC Analyses, was 67%.


Original PCA Image

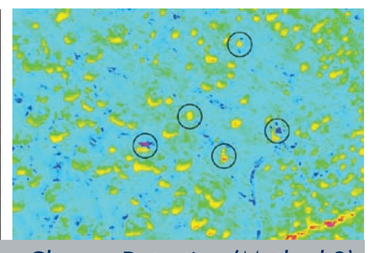

PCA 1 Image


PCA 2 Image

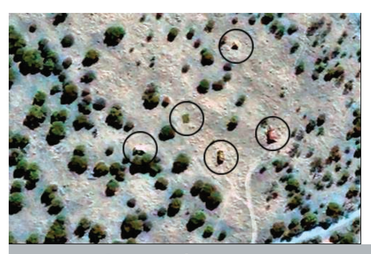

PCA 3 Image

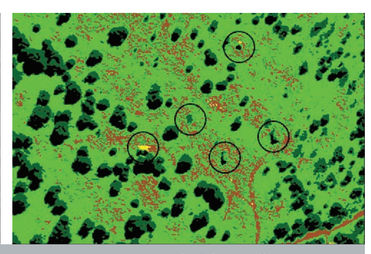
The second image analyses technique used was change detection. Image differencing (ID) is probably the most widely applied change detection algorithm [3]. It involves subtracting two images, taken at different dates, from each other. According to recent research, image differencing appears to perform generally better than other methods of change detection [1]. A major drawback is that seasonal changes reduce the probability of detection. During this exercise an EROS image was used as a reference image, and subtracted from the Quickbird image. The success rate of detecting camouflaged objects, using ID, was 56%.


Change Detection (Method 1)


Change Detection (Method 2)

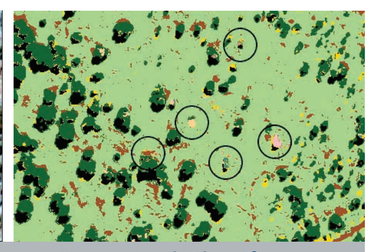
The third image analyses technique used was unsupervised classification. ERDAS Imagine software was chosen to implement the unsupervised ISODATA algorithm. This technique involves allowing the software to classify the image in a predefined number of classes. One of the drawbacks of this technique is that it has considerable difficulties dealing with the rich information content of high-resolution data (e.g. QuickBird). This produces inconsistent classification results and the software has difficulty in extracting the objects of interest. The success rate of detecting camouflaged objects, using this method, was 40%.


Original Image


Unsupervised Classification

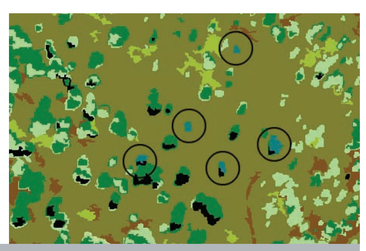
The fourth analyses technique used was supervised classification. The maximum likelihood technique was used. This algorithm assumes a Gaussian distribution of pixel values within each training class, therefore it tends to be more accurate in high-cluttered images. Areas with known properties were selected as training samples. These areas was selected from the so-called "calibration site", where nets and panels, having the reflectance properties of the targets, were displayed. The software used this training data and performed an inter-comparison to the rest of the image, which contained the camouflaged objects. Supervised classification had a 63% success rate of detecting camouflaged objects.


Original Image


Supervised Classification

The last image analyses technique applied to the imagery was object-based classification. eCognition, which permits object-oriented, multi-scale image analysis, was used. This technique can be used if any one of the shape, size and texture properties are known. This close relationship between
real-world objects and image objects vastly improves the detection probability. The 100% detection success rate of camouflaged targets was the best of all techniques used.


Original Image


Object-based Classification

CONCLUSIONS
- Because no track discipline was used most targets could visually be detected by looking at tacks and footpaths.
- Due to target orientation and the time of day, certain nets showed very high reflectance and could easily be detected.
- Principal component analysis shows promise in detecting camouflage objects. Camouflage objects are extracted from the 3rd or 4th PC (for Spot and Quickbird imagery) as an anomaly.
- The supervised and unsupervised classification technique had a 52% success rate in identifying camouflaged targets. The spectral properties of some of the nets matched the environment very well, causing signature overlap between the targets and the veld. This reduced the probability of detection.
- Object based classification techniques for camouflage detection out-perform current spectral based techniques, since these techniques do not take object features such as texture, shape, area and scale into account. The object-based classification technique had a 100% success rate in identifying camouflaged targets.

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