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Polarmetric and Hyperspectral Imaging for Detection of Camouflaged Objects

Gooch & Housego

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Optronic Laboratories LLC 4632 36th Street, Orlando, FL 32811
Tel: 1 407 422 3171 Fax: 1 407 648 5412 Email: info@olinet.com

Polarimetric and Hyper-spectral imaging for detection of camouflaged objects

White paper by
Gooch & Housego Ltd, Dowlish Ford, Ilminster, Somerset, UK TA19 0PF
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1. Introduction

The discrimination of targets from background is an ongoing issue in modern warfare. Two techniques of interest are polarisation and hyperspectral imaging both in the visible and short wave infra red (SWIR) bands. This innovation combines these capabilities in one sensor system with a common boresight and without fixed filters.

2. How the system works

The system takes advantage of both hyperspectral and polarisation techniques which are complementary to one another and significantly improve detection rates. The dynamic hyperspectral and polarimetric imaging system uses an acousto-optic tunable filter (AOTF) for fast spectral scanning of an environment to detect hidden targets and to provide optimum discrimination. The AOTF inherently provides two simultaneous filtered (monochromatic) orthogonally polarised images of a scene, in addition to an unfiltered white-light colour image. Since all of this information is viewed through a single boresight, registration of the three images is simplified. The novel and flexible AOTF enables the system to hunt for a specific spectral and polarisation profile of a target amidst an obscuring environment. Operation in the SWIR band provides optimum contrast between natural and man-made objects enhancing the detection and identification of targets. Target information is supplied to the operator/analyst in visual form at a high spatial resolution (600 lines) overlaid onto the white-light image, and/or may be integrated with imaging and reference data from other systems. The rugged all solid state design is suitable for mounting on airborne, land based or naval platforms, and the fast tuning speed (potentially <50µs/frame) gives the potential of real-time video imaging.

In its full implementation the system can provide:

i. White-light imaging (VIS/SWIR camera dependent): via the 0-order output. Refer to schematic.
ii. Multispectral imaging (SWIR): Function defined in software. Single-channel operation.
iii. Hyperspectral Imaging (SWIR): Function defined in software. Single-channel operation.
iv. Differential polarimetric hyperspectral imaging. Utilisation of both diffracted orders and comparing the two simultaneous images produced.

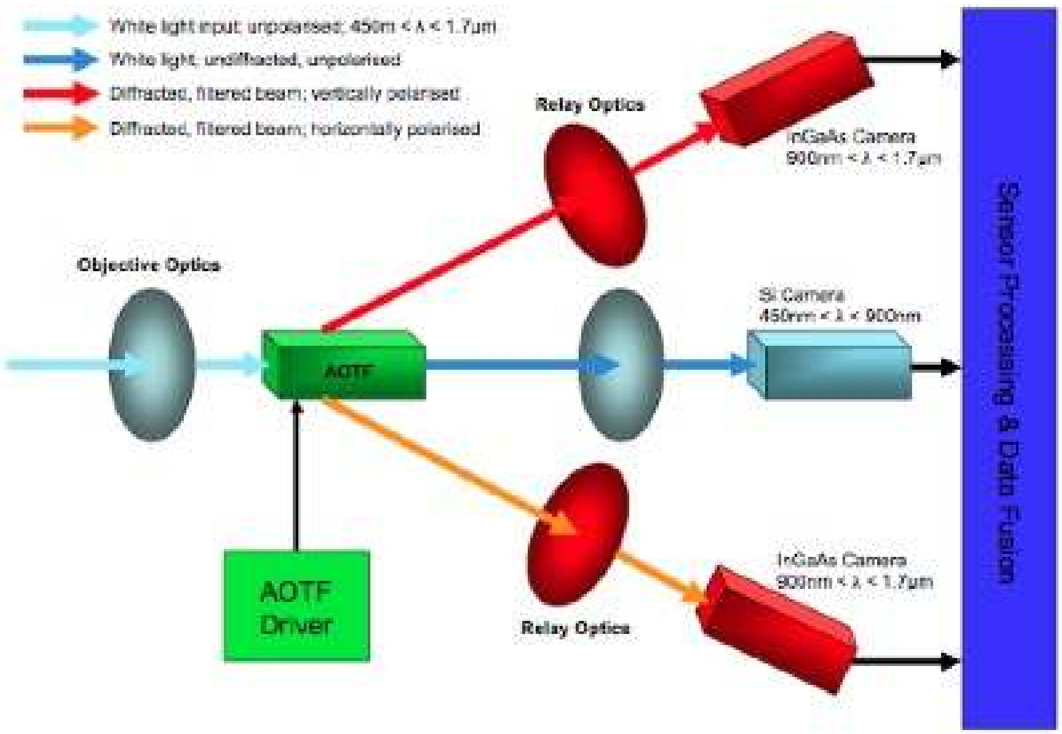


Figure 1 Schematic of polarimetric hyper-spectral imaging system

3. Features

The system can operate during day or night (The f-number for the SWIR cameras is f-9) and will have the capability to discriminate between multiple targets in real time. This includes the detection and characterisation of camouflaged targets (personnel and vehicles), targets in thermal equilibrium with their environment, direct/indirect fire events and mine/IED identification.

The proposed SWIR cameras within the system have an operating range from 0degC to +35degC, are shock mounted and the cameras have a degree of environmental protection. The camera system is sealed against airborne contaminants, moisture, sand and combustion fumes. The metal enclosure provides shielding against RF and ionising radiation. An extension of the temperature range to cover full military operational requirements is possible with the inclusion of internal temperature control.
The AOTF is inherently solid state with no moving parts. These devices are currently being further ruggedized for use in space applications. This technology will be available for devices used on ruggedized (flight) systems.

The camera and lens assemblies will be ruggedized to ensure effective operation within the anticipated environmental conditions. The ability of the SWIR cameras to image through glass enables conventional, cost-effective visible camera lenses to be used. This will also allow the assembly to be mounted inside a protective window enclosure providing additional benefits when positioning on land/sea/air vehicle platforms. The residual effects of visual anti-reflective coating can be software corrected within the system.
The system will provide surveillance and target tracking capabilities by scanning across known material spectra. This has been demonstrated in previous research with matched filter algorithms constructed from the spectrum of a vehicle in one image and successfully used to track the vehicle movements. The same filter was also used to detect the spectrum of the vehicle under camouflage

The targets can be illuminated with a variety of laser wavelengths (1.064 µm, 1.3µm, 1.55µm) in both day and night time to covertly illuminate a scene that can be viewed only with SWIR cameras. For example, illuminating a route to safety navigate a military vehicle through hostile territory when nightglow is unavailable. The cameras can be tuned to these wavelengths in-order to isolate interfering light sources.

The system will enable fast scanning across the entire waveband of 900nm to 1700nm (SWIR) and by using dynamic filtering provided by the AOTF, it is reprogrammable in the field to wavelengths of interest enabling the identification of targets against the background.

4. Examples

Vegetation can be separated from a background by spectrally classifying an image by chlorophyll absorption.

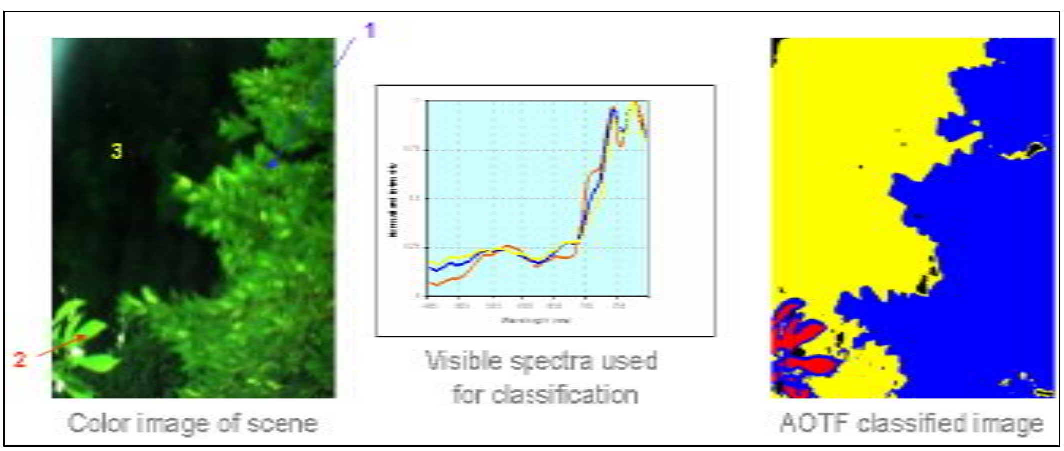


Figure 2: Vegetation discrimination

Man made objects such as mines hidden in similarly coloured gravel can be detected by classification of spectral features in the SWIR. The mines are highlighted to the observer by false colour overlay (red and blue)

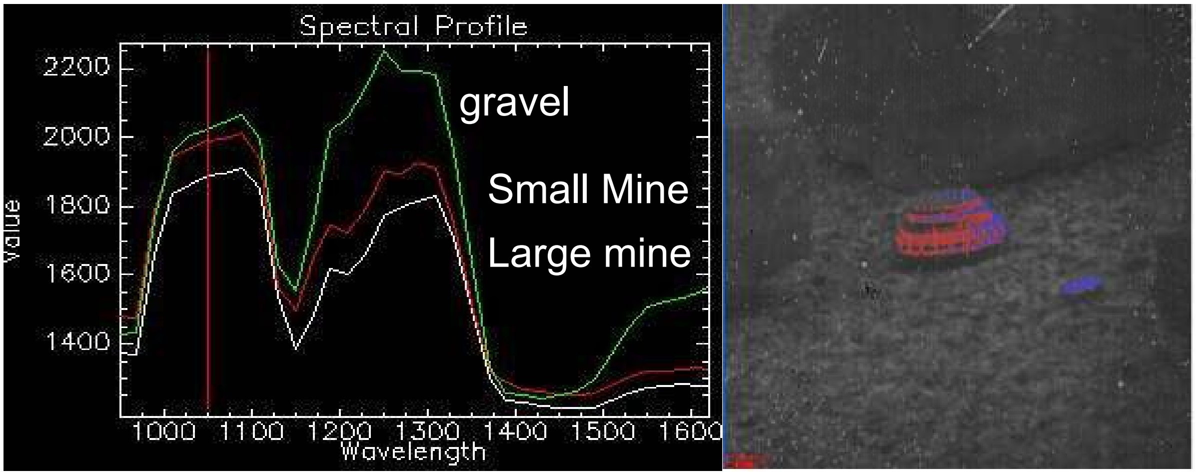


Figure 3 Spectral classification and detection of mines

Man made objects such as mines (green and red foreground) and a camouflarged jacket (blue in background) are detected by SWIR spectral classification. Once the spectal profile of a target is programmed into the HSI system other similar targets can be detected and tracked as they move through a scene.

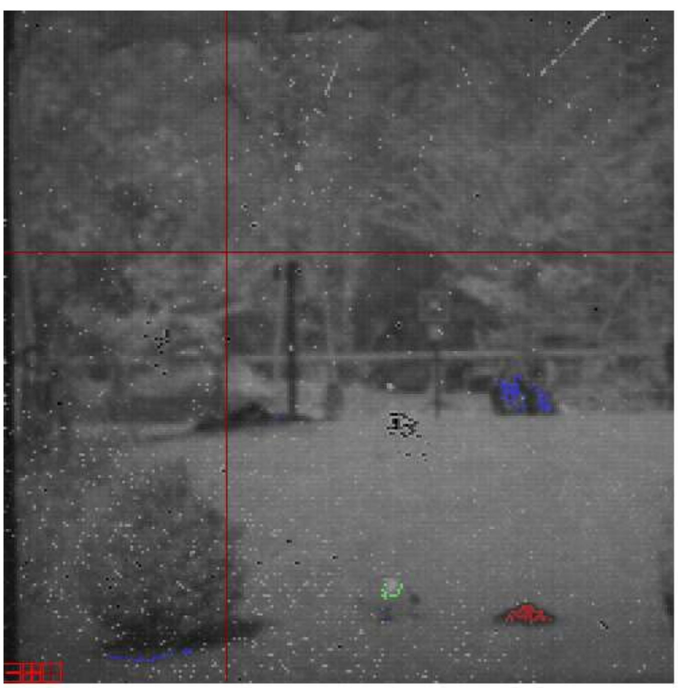
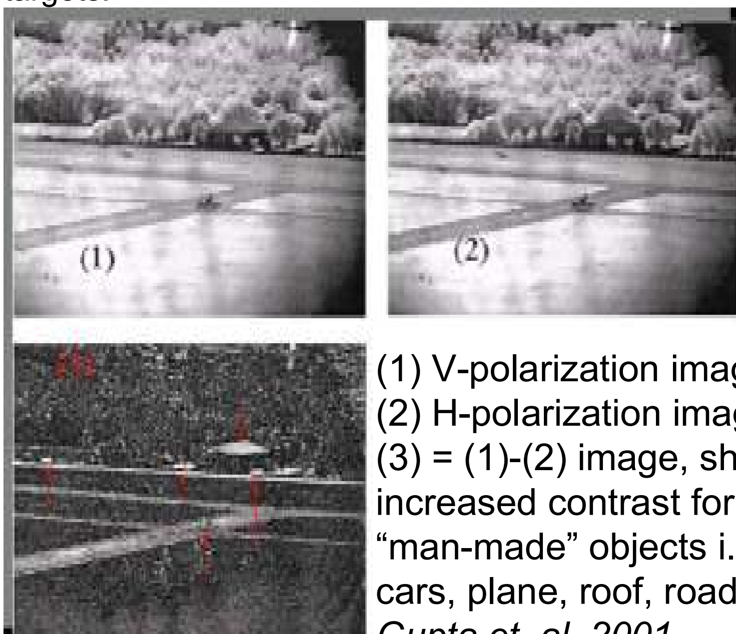


Figure 4 Detection of camoflaged objects at SWIR wavelengths

Differential polarisation detection enhanced the contract of hidden man-made objects so that they can be detected. Combining hyper-specrtral imaging and polarisation detection increases the success rate of detecting camoflarges targets.



(1) V-polarization image @ 740nm
(2) H-polarization image
(3) = (1)-(2) image, showing increased contrast for "man-made" objects i.e. cars, plane, roof, roads.
Gupta et. al. 2001

Figure 5 Enhancement of detection by differential polarisation imaging

5. Applications

5.1.1 Air Force

The system deployed on either manned or unmanned aircraft will ultimately be used by the aircraft operators and imagery analysts to support activities such as reconnaissance, urban operations and force protection.

5.1.2 Army

Analysts on the ground will be able to use the imagery provided by the system to support other Geospatial Information System (GIS) activities such as terrain analysis. The deployment of the system onto land platforms will provide flexible surveillance and the potential for integration with other existing sensor technologies (e.g. Laser Range Finders (LRFs) and Thermal Imagers (TIs)).

5.1.3 Navy

The system provides improved imaging against rough sea background and could support various naval activities such as coastal patrols, counter-insurgent operations and narcotics trafficking. The system could be deployed on individual vessels or imagery information sent via secure video links from airborne platforms to naval operators/analysts. The system has the potential to provide enhanced Search And Rescue (SAR) capability for locating small objects in a cluttered environment. This would significantly enhance the capabilities of systems such as Airborne Real time Cueing Hyperspectral Enhanced Reconnaissance) ARCHER that are currently used for SAR operations.

Hyperspectral imaging has been shown to increase the spatial resolution of camera systems for identifying small objects in a large Field of View (FoV) (reference: Subpixel object detection using hyperspectral imaging for search and rescue operations Subramanian, Suresh; Gat, Nahum Proc. SPIE Vol. 3371, p. 216-225).

5.1.4 Defence Command

The system will support defence command activities by providing real time intelligence improving tactical response in scenarios including force/base protection and reconnaissance.

5.1.5 Defence Intelligence

The system could be used by imagery analysts in defence intelligence to provide improved situational awareness, threat detection/hazard avoidance, assessment and the Intelligence Preparation of the Battlefield (IPB) in support of counter-insurgent, urban operations, force protection and countering illegal activities.
The operator/analyst will receive imaging requests for either a particular area of interest or for a specific object in order to obtain its spectral profile. The operator/analyst will programme the system, i.e. ‘detect vehicle’, which auto-selects camera functions) to specify the bandwidth/wavelengths of interest. Signal processors within the system will manipulate the raw data acquired by all three cameras to provide real time imagery to the operator/analyst. This will ultimately be disseminated in the form of intelligence to the end user.