ARMY RESEARCH LABORATORY

Spectral Discrimination of a Tank Target and Clutter Using IBAS Filters and Principal Component Analysis

by Karl K. Klett, Jr.

ARL-TR-5599 **July 2011**

Approved for public release; distribution unlimited.

NOTICES

Disclaimers

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Citation of manufacturer's or trade names does not constitute an official endorsement or approval of the use thereof.

Destroy this report when it is no longer needed. Do not return it to the originator.

Army Research Laboratory
Adelphi, MD 20783-1197

ARL-TR-5599 **July 2011**

Spectral Discrimination of a Tank Target and Clutter Using IBAS Filters and Principal Component Analysis

Karl K. Klett, Jr.
Sensors and Electron Devices Directorate, ARL

Approved for public release; distribution unlimited.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.
PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE *(DD-MM-YYYY)* July 2011	**2. REPORT TYPE**	**3. DATES COVERED (From - To)** March 2011
4. TITLE AND SUBTITLE Spectral Discrimination of a Tank Target and Clutter Using IBAS Filters and Principal Component Analysis		**5a. CONTRACT NUMBER** **5b. GRANT NUMBER** **5c. PROGRAM ELEMENT NUMBER**
6. AUTHOR(S) Karl K. Klett, Jr.		**5d. PROJECT NUMBER** **5e. TASK NUMBER** **5f. WORK UNIT NUMBER**
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Research Laboratory ATTN: RDRL-SEE-E 2800 Powder Mill Road Adelphi MD 20783-1197		**8. PERFORMING ORGANIZATION REPORT NUMBER** ARL-TR-5599
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		**10. SPONSOR/MONITOR'S ACRONYM(S)** **11. SPONSOR/MONITOR'S REPORT NUMBER(S)**

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Infrared images of a tank and background clutter are analyzed to investigate if the chromaticity plane can be used as a cueing aid for automatic target detection. Three images were acquired using the clear aperture and two classified filters that comprise the B-kit installed FLIR that is part of the Improved Bradley Acquisition System (IBAS). 5 by 5 pixel samples of the image are plotted on the chromaticity plane from various locations on the target and background clutter. The multi-spectral imagery is transformed into a 3D color space which increases the dynamic range of the image information. Such a transformation of target and background pixel, to the plane formed by the second and third principal component, placed pixels at different locations in the chromaticity plane, where their position is compared.

15. SUBJECT TERMS

Principal components, chromaticity plane, target discrimination

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
					Karl K. Klett, Jr.
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** (*Include area code*)
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UU	18	(301) 598-6910

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

Contents

List of Figures **iv**

Executive Summary **v**

1. Introduction **1**

2. Methods, Assumptions, and Procedures **1**

2.1 Principal Components and the Chromaticity Plane 1

2.2 Constructing Principal Components from the Correlation Matrix 2

3. Results and Discussion **4**

3.1 Analysis Techniques 4

3.2 Background Pixel Location in the Chromaticity Plane 4

3.3 Target Pixel Location in the Chromaticity Plane 5

4. Conclusion **6**

5. References **8**

Distribution List **9**

List of Figures

Figure 1. Relationship between principal component transformation and the chromaticity plane. 2
Figure 2. Clear aperature IBAS image showing an M60 tank at 1 km. 3
Figure 3. Tank image extracted from figure 2. 3
Figure 4. Figure 3 pixel locations in the chromaticity plane (eigenvector 2 and 3). 4
Figure 5. Background pixel locations in the chromaticity plane. The white square box shows where the pixel samples were taken. 5
Figure 6. Target pixel locations in the chromaticity plane. The white square box shows where the pixel samples were taken. 6
Figure 7. Target and background separation in the chromaticity plane (see figure 1). 7

Executive Summary

This report describes a technique to separate targets from their background, using the 2nd and 3rd principal components which form the chromaticity plane. The chromaticity plane contains information about the hue and saturation (the color) of images. Three images were analyzed in the infrared, which were acquired from an Improved Bradley Acquisition System (IBAS) system between 8–14 microns. Two of the images were acquired using different IBAS filters and one image was obtained using no filter.

The analysis was done on a cropped image of a tank, taken from a larger image. Small sections of the background and tank target were transformed into the chromaticity plane. Differences in pixel location in the chromaticity plane, between the tank target and the background, were noted. Both background and tank target hue values vary widely. The background saturation is approximately constant. This seems to indicate, for this analysis, a target can be differentiated from the background by the target or background saturation value in the chromaticity plane.

INTENTIONALLY LEFT BLANK.

1. Introduction

In the infrared, targets and their background periodically have the same contrast due to radiant intensity variations of objects compared to their background, the targets having large positive contrast at one time of the day and large negative contrast at others. In the transition from large positive contrast to large negative contrast, the object passes through a crossover point, which is the point at which the contrast difference between the object and the background is zero.

The Improved Bradley Acquisition System (IBAS) system uses an 8–14 micron detector, and in the LWIR the photon flux emitted by the object is proportional to its surface emissivity. The radiant spectra, defined by the Planck function, is dependent only on temperature. This contrasts with the conditions in the VIS, NIR, and SWIR where the photon flux is primarily dependant upon surface reflectivity.

This analysis investigates if principal component analysis can be used, with existing IBAS filters, to differentiate the emissivity of targets and background clutter. Thus, this analysis is an effort to distinguish infrared color, which is defined by emissivity. This multi-spectral analysis uses the B-Kit installed FLIR filters. Emissivities of materials vary by wavelength, and this analysis is an effort to take advantage of these emissivity changes at various wavelengths.

2. Methods, Assumptions, and Procedures

2.1 Principal Components and the Chromaticity Plane

Principal Component analysis, when applied to image processing, selects axes along brightness variations of the pixel data, the largest variation corresponding to the first principal component, the second largest variation corresponding to the second principal component, etc. These relationships are shown in figure 1. When applied to image processing, the first principal component is always aligned with the largest pixel brightness variation. The principal components also correspond to eigenvectors, and their construction is described in section 2.2. Figure 1 shows that considering pixel information is useful because the brightness information is separated from the color information. The largest spatial dimension of the prolate spheroid of transformed pixels extends along the first principal component. This first principal component aligns with brightness variations, and the color information is orthogonal to the first principal component in what is called the chromaticity plane, which is the plane formed by the 2nd and 3rd principal components. The chromaticity plane, shown in polar coordinates, depicts hues varying from 0 to 360 degrees and saturation values in the radial direction.

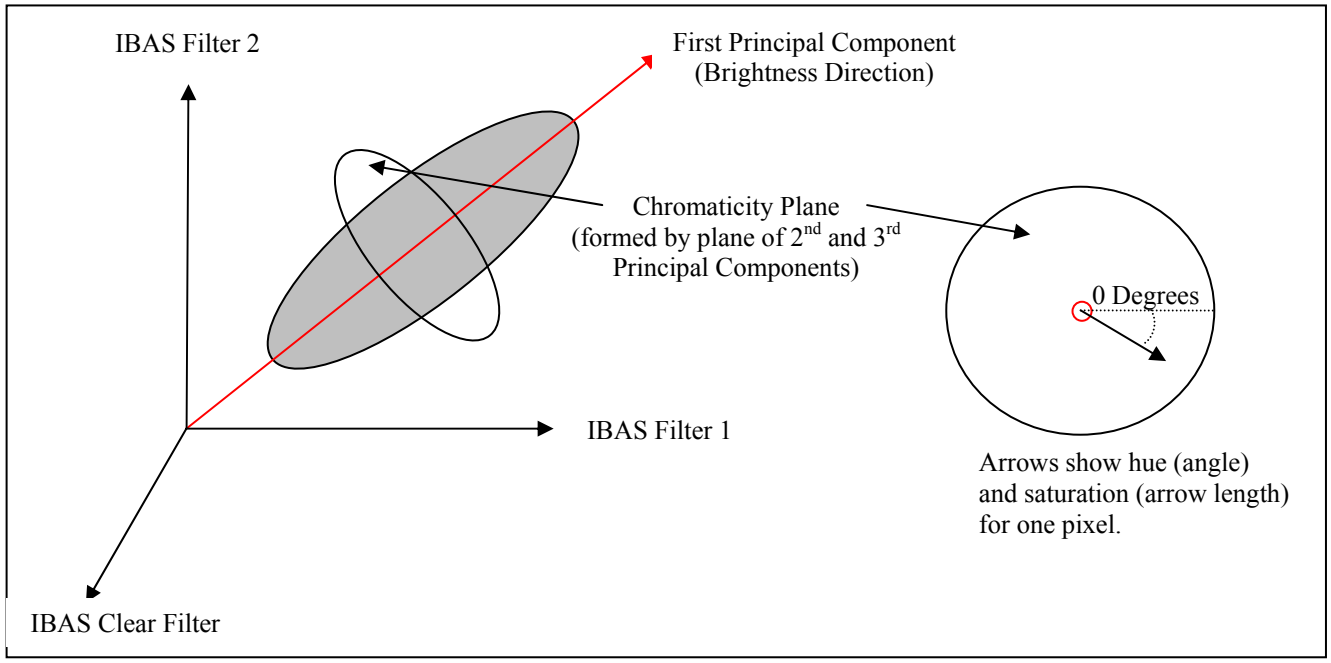

Figure 1. Relationship between principal component transformation and the chromaticity plane.

2.2 Constructing Principal Components from the Correlation Matrix

Three images of a scene, containing an M-60 tank at a distance of 1 km are shown in figure 2. These images were obtained using the clear aperature, the #1 and #2 filters of the IBAS system. IBAS uses a scanning linear array, which has 13 X 13 micron pixels. Each pixel, from the tank scene, maps 0.133 m from object space. The scene of the tank was cropped, and principal components calculated from this cropped image are shown in figures 4–6.

Figure 2. Clear aperature IBAS image showing an M60 tank at 1 km.

The elements of the correlation matrix, from which the eigenvectors (principal components) are constructed, are calculated is:

$$\sigma_{ij} = [\Sigma_{n=1}^{N} (CCD_i)_n(CCD_j)_n) - (CCD(avg)_i)(CCD(avg)_j)N. \quad (1)$$

CCD_i and CCD_j are individual pixel values of the three images. The indices, i and j, which vary from 1 to 3, represent the following physical filter conventions: 1-clear aperature, 2-IBAS filter 1, 3-IBAS filter 2. N is the number of pixels in the CCD image and n is a specific pixel in the CCD matrix.

The cropped portion of figure 2, showing only the M60 tank, is shown in figure 3, along with the projection of the image's pixel values in the chromaticity plane as shown in figure 4.

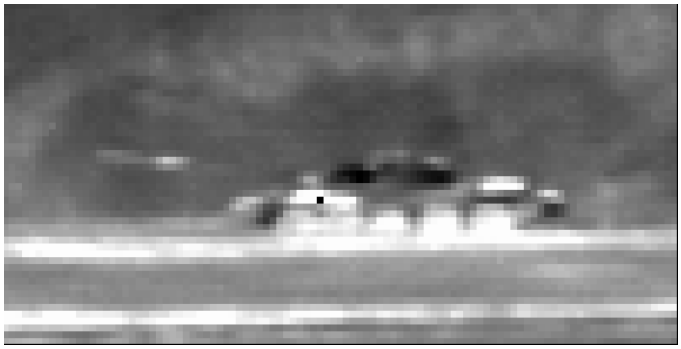

Figure 3. Tank image extracted from figure 2.

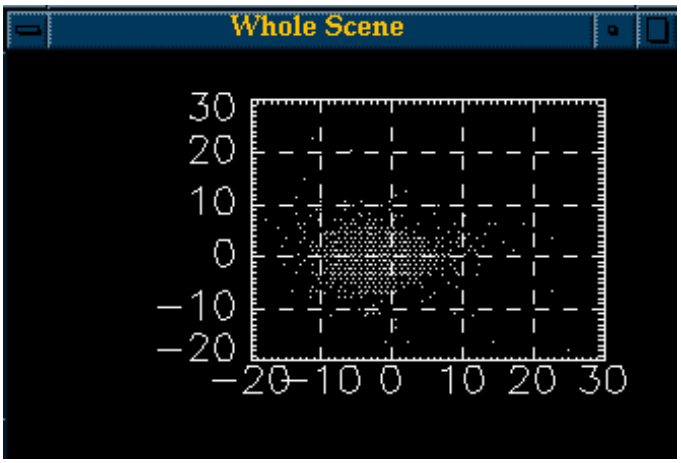

Figure 4. Figure 3 pixel locations in the chromaticity plane (eigenvector 2 and 3).

3. Results and Discussion

3.1 Analysis Techniques

Twenty five pixels, located within a 5 X 5 pixel area, were analyzed at various locations on the target (the tank) and in the background. Equation 1 was used to evaluate these pixels and extract them from figure 3. These pixels measure the emissivity, and the transformation to the chromaticity plane provides a way to determine the infrared hue and saturation, represented by an individual pixel's angular deviation from 0 degrees and its distance from the origin respectively, as shown in figure 1.

3.2 Background Pixel Location in the Chromaticity Plane

The following images show where pixels from different background locations lie in the chromaticity plane. Notice that, in this case, the background pixels map into the chromaticity plane along the hue orientation of zero degrees, when measured based on the convention in figure 1. This shows that the emissivity of the background is rather uniform, since in the infrared, emissivity defines color in a similar way that surface reflectivity defines color in the visible. Hue corresponds to color, and saturation is the depth or the intensity of the color.

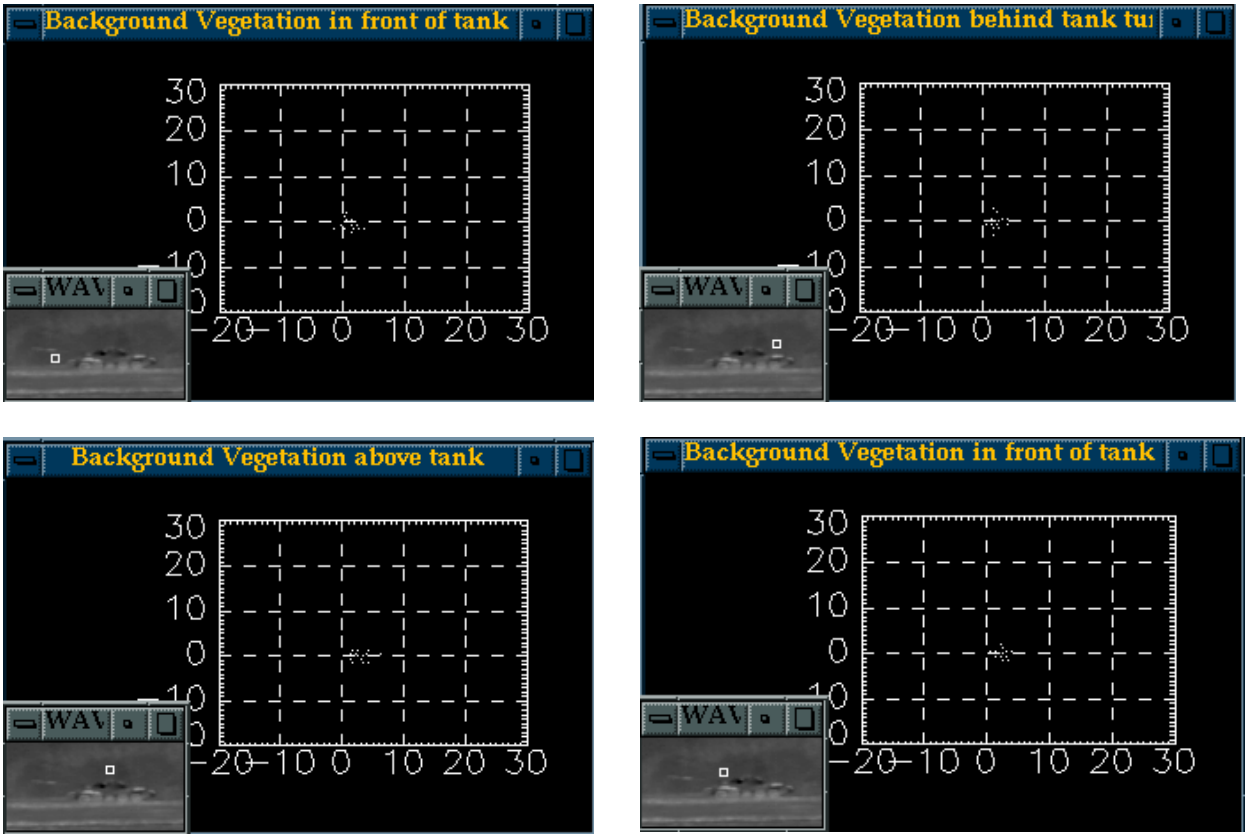

Figure 5. Background pixel locations in the chromaticity plane. The white square box shows where the pixel samples were taken.

3.3 Target Pixel Location in the Chromaticity Plane

The following images show where pixels from different target locations lie in the chromaticity plane. Note the difference between the target pixel locations (figure 6) compared with the background pixel locations (figure 5) in the chromaticity plane. Many pixels in figure 6 have hue orientations greater than 90 degrees and saturation vector lengths greater than those shown in figure 5.

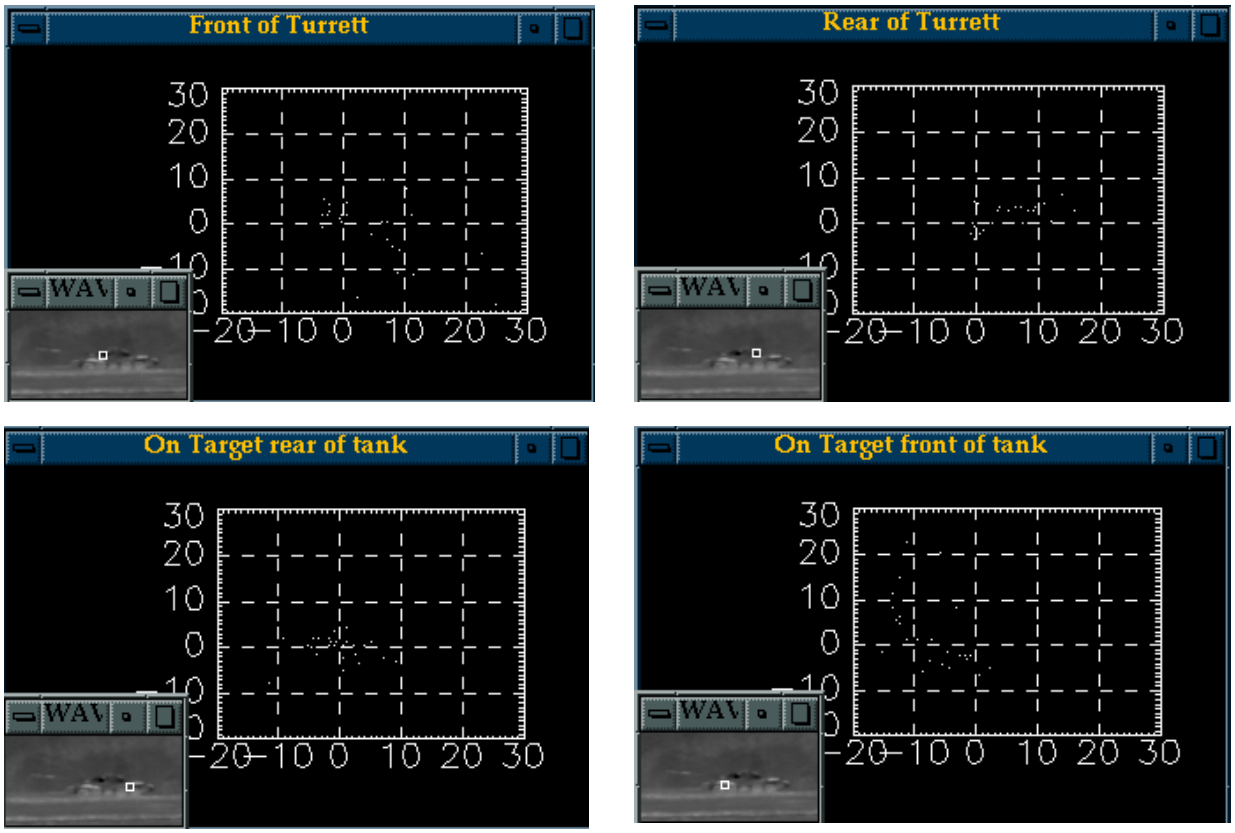

Figure 6. Target pixel locations in the chromaticity plane. The white square box shows where the pixel samples were taken.

4. Conclusion

Principal component analysis has been used to analyze an IBAS 8–14 micron image of a tank and the background. Pixels that make up the scene (tank and background) were plotted in the chromaticity plane, which is the plane formed by the 2nd and 3rd principal component vectors. When the pixels of the image are plotted in the chromaticity plane, saturation and hue are similar for various background locations. The saturation and hue, particularly the hue, show large variations on the target compared to the background. In this example, the background and target are separated (primarily in hue), as shown below, which might warrant further investigation of this phenomena as a target detection technique.

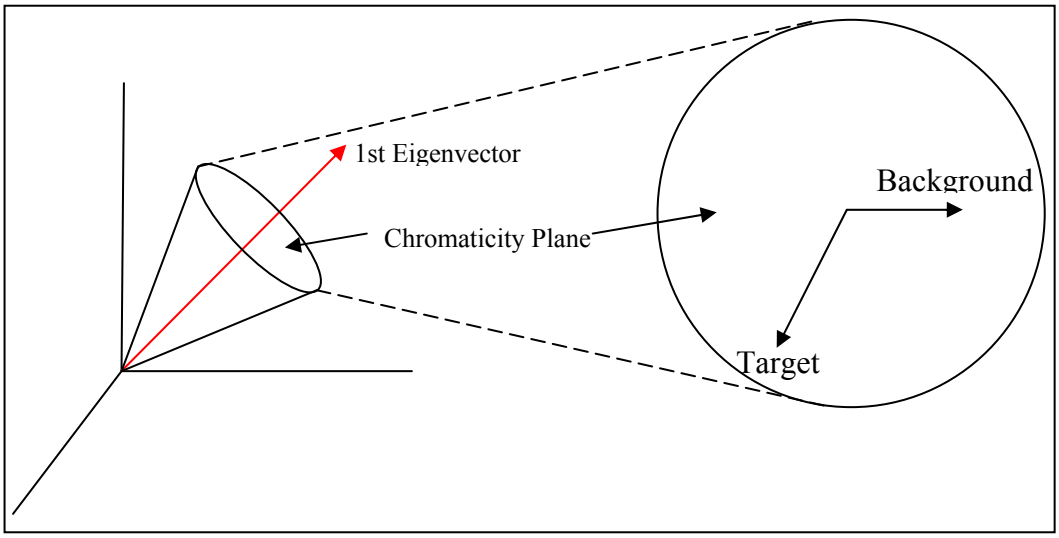

Figure 7. Target and background separation in the chromaticity plane (see figure 1).

5. References

1. D'Zmura M.; Lennie P. Mechanisms of Color Constancy. *J Opt. Soc. Of Am.* **1986**, *A3*, 1662.

2. Maloney L. T.; Wandell, B. A. Color Constancy: A Method for Recovering the Surface Spectral Reflectance. *J. Opt. Soc. Am.***1986**, *A3*, 1673–1683.

3. Scribner, D. Extending Color Vision Methods to Bands Beyond the Visible. *Machine Vision and Applications* **2000**, *11*, 301–312.

4. Scribner, D., et al. Infrared Color Vision: Separating Objects from Background. *Proc. SPIE 3379* (SPIE Press, Bellingham, Wash, 1998) pp. 14–17.

NO. OF COPIES	ORGANIZATION
1 ELECT	ADMNSTR DEFNS TECHL INFO CTR ATTN DTIC OCP 8725 JOHN J KINGMAN RD STE 0944 FT BELVOIR VA 22060-6218
1 CD	OFC OF THE SECY OF DEFNS ATTN ODDRE (R&AT) THE PENTAGON WASHINGTON DC 20301-3080
1	US ARMY RSRCH DEV AND ENGRG CMND ARMAMENT RSRCH DEV & ENGRG CTR ARMAMENT ENGRG & TECHNLGY CTR ATTN AMSRD AAR AEF T J MATTS BLDG 305 ABERDEEN PROVING GROUND MD 21005-5001
1	PM TIMS, PROFILER (MMS-P) AN/TMQ-52 ATTN B GRIFFIES BUILDING 563 FT MONMOUTH NJ 07703
1	US ARMY INFO SYS ENGRG CMND ATTN AMSEL IE TD A RIVERA FT HUACHUCA AZ 85613-5300
1	COMMANDER US ARMY RDECOM ATTN AMSRD AMR W C MCCORKLE 5400 FOWLER RD REDSTONE ARSENAL AL 35898-5000
1	US GOVERNMENT PRINT OFF DEPOSITORY RECEIVING SECTION ATTN MAIL STOP IDAD J TATE 732 NORTH CAPITOL ST NW WASHINGTON DC 20402
11	US ARMY RSRCH LAB ATTN IMNE ALC HRR MAIL & RECORDS MGMT ATTN RDRL CIO LL TECHL LIB ATTN RDRL CIO MT TECHL PUB ATTN RDRL SEE E K ALIBERTI ATTN RDRL SEE E K KLETT, JR. (5 COPIES) ATTN RDRL SEE M L STOUT ATTN RDRL SEE P GILLESPIE ADELPHI MD 20783-1197
TOTAL:	18 (16 HCS, 1 CD, 1 ELECT)

INTENTIONALLY LEFT BLANK.