

Image processing technique to differentiate between a decoy and real objects

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Abstract— Modern day warfare is primarily based on stealth and surprise. The surprise elements are achieved through various means, in which one of the means being Camouflage and concealment. The aim of camouflage is to hide the generic signature of a weapon system or human being in such a way that it becomes or appears to be a part of background or general terrain where we are operating.

In the modern era, polarization is building off many research and developments in the field of Automatic Target Detection and Recognition. This research in Polarization Vision has continued with the development of a material classification method having the capability of detecting metallic materials under polarized illumination of clear skylight, complementary in nature to existing methods. New photometric invariants have been discovered for object recognition under multiple light illuminations based upon the relationship between the local covariance matrix of photometric values and Gaussian curvature. In this research work, the interaction and Polarization of light with material is analyzed using image processing technique to differentiate between a decoy and real objects.

Keywords— *Real and Decoy materials, Decoy, decoy techniques, material classification, Image processing techniques, Recognition, polarization of material*

1 INTRODUCTION

One of the primary means of surprise for the weapon system is to use "Decoys". Decoys are a replica of an item in such a way that it appears to be real visually. However the material used is different, having different EM wave properties. This gives an idea that if we can discern the EM properties of real object and decoy we should be able to differentiate between real and decoy objects. So to do this we used the polarization vision with the help of polarizer. Polarization vision is an important visual extension to both intensity and color to which human vision is oblivious. There are polarization parameters of light that are physically orthogonal to color and intensity and that are therefore immune to modified or degraded extrinsic "appearance" of objects created by intensity and/or color camouflage, and, clutter. These polarization parameters are instead directly related to the intrinsic material composition, surface roughness, and shape of objects and also give strong physical motivation for applying such a sensory modality towards the goal of detecting and recognizing target objects that independent of extrinsic intensity and color appearance.

Decoys (e.g., a painted military vehicle on canvas) that are made to have the extrinsic appearance of a target may be distinguished in the polarization domain if they differ in material and geometric characteristics from actual targets.

As we know light being an electromagnetic wave has the property to possess different polarization states. White light is randomly polarized, when any material is illuminated by white light, it reflects and scatters the light. These phenomena change the polarization state of the incident light. The way in which each material interacts with incident light and how it changes its polarization state can be investigated to establish unique characteristics of a material. These characteristics can further be utilized to identify and recognize them from each other's. [1]

Response of Materials to Incident light

1. Non-metallic substances reflect light polarized paral-

lel to their surfaces more than light polarized vertically.

2. The metallic media is populated with conduction band electrons, which are in general capable of reacting against the photon-applied accelerating force. And, because there are no gaps in the conduction band, there is no significant transmission, or absorption at any frequency. Thus, the metal will reflect all frequencies of visible photons, and in general reflect a higher percentage of those photons at all angles.
3. Polaroid material is composed of plastic with long molecules drawn so that the molecules are arranged side by side, all pointing in one direction. When the E field of the photon vibrates in the same direction as the molecule in the Polaroid film, the energy of the photon is absorbed and does not transmit through that Polaroid material. Thus, when the Polaroid film and its constituent long molecules are oriented horizontally, it will block horizontally polarized photons. Vertically polarized photons will pass through these molecules because there is no current induced that can flow a distance and dissipate the energy by the collision of the electrons.

2 MEASUREMENTS PROCEDURE:

We used an absorptive linear polarizer with marked angular graduations to capture the reflected light at different polarization angle. The reflected light from the decoy is randomly or partially polarized, for our detection and identification purpose we need to convert the polarized light to linearly polarized light. From the Malus's law for an ideal polarizer the light intensity is proportional to the square of the amplitude, so that the dependence of the intensity with polarizer angle is

$$I(\theta) = I_0 \cos^2 \theta \quad (1)$$

Where I_0 is the initial intensity and θ is the angle between the light's

initial polarization direction and the axis of the polarizer. [2]

However for each angular graduation we can find the intensity value in terms of I_0 :

Table 1: Intensity variation with polarization angle

θ	$I(\theta) = I_0 \cos^2 \theta$ (in terms of I_0)
0	1
30	0.023794
60	0.90709
90	0.20077
120	0.662891
150	0.488952
180	0.358154
210	0.781239
240	0.106133
270	0.969008
300	0.000488
330	0.982475

2.1 POLARIZATION BY SCATTERING

When light strikes the atoms of a material, it will often set the electrons of those atoms into vibration. The vibrating electrons then produce their own electromagnetic wave that is radiated outward in all directions. This newly generated wave strikes neighboring atoms, forcing their electrons into vibrations at the same original frequency. These vibrating electrons produce another electromagnetic wave that is once more radiated outward in all directions. This absorption and reemission of light waves causes the light to be scattered about the medium. This scattered light is partially polarized. [3], [9]

Models of light scattering can be divided into three domains based on a dimensionless size parameter, α which is defined as

Where

πD_p is the circumference of a particle
 λ is the wavelength of incident radiation

Based on the value of α , these domains are:

$\alpha \ll 1$: Rayleigh scattering (small particle compared to wavelength of light)

$\alpha \approx 1$: Mie scattering (particle about the same size as wavelength of light)

$\alpha \gg 1$: Geometric scattering (particle much larger than wavelength of light).

The decoy material will reflect and scatter the incident light. The light from the object will interfere with the atmosphere and will further undergo polarization due to atmospheric scattering. Therefore for our purpose we will be dealing with Rayleigh and Geometric scattering.

The atmospheric scattering of light is governed by Rayleigh

scattering. The amount of Rayleigh scattering that occurs for a beam of light depends upon the size of the particles and the wavelength of the light. Specifically, the intensity of the scattered light varies as the sixth power of the particle size, and varies inversely with the fourth power of the wavelength. The intensity I of light scattered by a single small particle from a beam of unpolarized light of wavelength λ and intensity I_0 is given by:

$$I = I_0 \frac{1 + \cos^2 \theta}{2R^2} \left(\frac{2\pi}{\lambda} \right)^4 \left(\frac{n^2 - 1}{n^2 + 2} \right)^2 \left(\frac{d}{2} \right)^6$$

R is the distance to the particle

θ is the scattering angle

n is the refractive index of the particle and

d is the diameter of the particle. [4], [2], [10]

Now we will discuss about the image and recognition techniques. Digital images are composed of pixels (short for picture elements). Pixel is like a tiny dot of a particular color. A digital image is a rectangular array of pixels sometimes called a bitmap. The density of pixels in an image is referred to as its resolution. The higher the resolution, the more information the image contains. If we keep the image size the same and increase the resolution, the image gets sharper and more detailed. [5], [7]

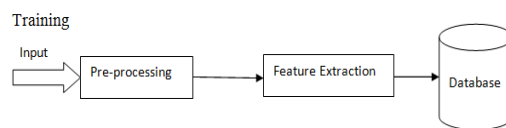
Some of the common features used in computer vision system are mean standard deviation, energy, entropy, skewness, kurtosis and second order statistics.

3 IMPLEMENTATION

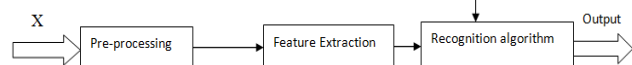
The implementation of the above mentioned method takes place in 4 major steps

1. Acquiring the image
2. Pre processing
3. Feature vector extraction
4. Training Database construction/Recognition algorithm
5. Output

Training



Recognition



System Realization

Step 1: Acquisition of Image

For practical testing purposes the images of sample/test materials were captured at different polarization angles. This was achieved by placing a polarizer with angular graduation in front of a digital camera.



Fig.1 Polarizer with angular graduations

A Nikon10 Megapixel digital camera was used to capture image. The images were captured in a room under uniform lightning condition. The images were stored in jpeg format on the hard drive of laptop.

Step 2: Pre-Processing

In this section the images are cropped to select only the region of interest. These images are then read into MATLAB program and are converted from RGB to greyscale image to simplify the processing.

Step 3: Feature Extraction

Now using MATLAB image processing tools we extract several features from the image such as contrast, kurtosis, skewness, entropy, standard deviation, correlation, energy, homogeneity and HU moments are extracted.

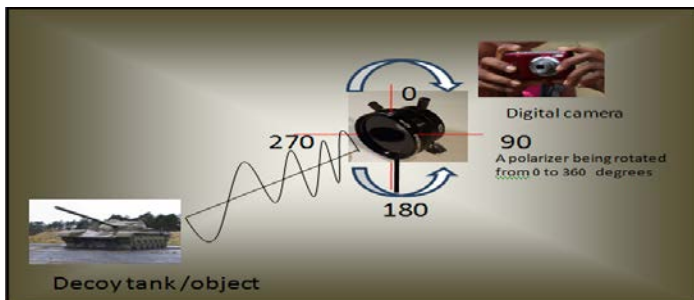


Fig.2 Experimental set up

In this research we have extracted the following feature vectors from the captured images for its analyses:

1. Correlation
2. Homogeneity
3. Energy
4. HU 1st moment (Φ_1)
5. HU 2nd moment (Φ_2)

Step 4: Training Database Construction/Recognition

Having extracted the features, the process proceeds depending on whether we are creating and expanding our data-

base or recognizing an object.

I. Training

The training image database is basically the collection of digital images taken by a digital camera. After feature vector extraction the images are stored in order to act as a reference or standard for the recognition process.

The database consists of images of

1. An iron piece
2. A plastic (PVC) piece
3. A Stainless steel container
4. A Tin can
5. A wooden object
6. The Aluminium can
7. A Rubber Tyre with plastic alloy
8. A pure iron part
9. A canvas material
10. A leather material

For each material 12 images were captured at following polarization angles: 0, 30, 60, 90, 120,150,180,210,240,270,300 and 330. Hence the database consists of a total of $12 \times 10 = 120$ images. Such as:

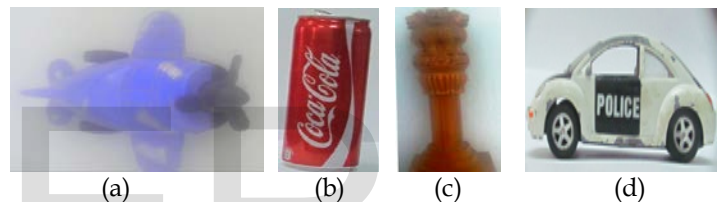


Fig.3 A set of images showing training image database (a) A plastic piece (b) A tin can (c) A wooden piece (d) An iron piece

All the images are in gray scale format and are available in jpeg and png format.

I. Recognition

On the other hand if our current aim is to recognise and enemy object, the process follows the recognition path. In this section the features extracted from the image are input to the recognition algorithm developed in MATLAB. The algorithm compares the feature value of the unknown object to the values of the same feature of the objects stored in our database by calculating Euclidian distance. A max error of 0.01 is defined as a threshold while calculating this distance.

Step 5: Output/Result

The recognition process after comparing each feature of the unknown object to that of the database materials identifies the object as either one of that in the database and prints the result "Object Identified as Wood" or else prints "Object not found in database" as output

3.1 TRAINING DATABASE CONSTRUCTION

Generally the training image database is very large, this is so because for increasing the probability in recognition process, a large number of feature vectors are extracted in our case to the database is very large as for each material, images are captured at twelve different polarization angles, and thus each

material has twelve images. Now for each image 18 features are extracted which are:

1. Mean
2. Standard Deviation
3. GLCM- Contrast
4. GLCM- Correlation
5. GLCM- Energy
6. GLCM- homogeneity
7. GLCM with 45deg offset- Contrast
8. GLCM with 45deg offset - Correlation
9. GLCM with 45deg offset - Energy
10. GLCM with 45deg offset - homogeneity
11. HU 1st moment
12. HU 2nd moment
13. HU 3rd moment
14. HU 4th moment
15. HU 5th moment
16. HU 6th moment
17. HU 7th moment
18. HU 8th moment

Although 18 feature vectors have been calculated, but on analysis of training data showed that only five feature vectors are having sufficient difference in the value to make it a dominant feature vectors.

Though we are only using 5 for our purpose but for references purpose and we do need to store all the data. Thus our data becomes, Image size $\times 12 \times 18 \times 8 =$ _____ bits of data, for example for an image with size 640×720 the bytes required $= 640 \times 720 \times 12 \times 18 \times 8 = 79626240$ bits or 9953280 bytes. This is for one material, as the library or materials keeps increasing the training image database size increases exponentially. Also for the recognition pattern to work smoothly we need to store the data in a well-organized tabular manner.

3.2 MATLAB interface with MS EXCEL

The features are calculated using MATLAB image processing tools. The data from feature extraction process has to be stored in a very sophisticated and organized way for the recognition algorithm to extract it for computational purposes. The best way to organize our data is to tabularize the data, and for this purpose we use Microsoft Excel. For each material a spread sheet is created, the polarization angles are arranged in a column and the feature headings in a row, now for each angle all feature vectors are directly written into the spread sheet from MATLAB.

Below is an image showing how data of Stainless steel is stored into the spread sheet. Similarly a sheet is created for each material in MS excel.

NOTE: The image shown is cropped and scaled to fit due to size constraints.

Fig.4 an Excel Sheet for Stainless Steel

During the recognition process the data is extracted easily for each material from the spread sheet. The values are then compared with that of the unknown object and Euclidian distance is computed to find the closest material which the object resembles.

Each feature vector comparison gives a result; either the object is identified as say "iron" or else "not". It is possible that one feature computation gives the result iron whereas other gives a result Aluminum. We apply Max sum rule to establish a single result i.e. each time iron is printed as a result its count increases. After calculating several feature vectors the material with max count is declared as the unknown object material. Below image shows how the max sum rule is applied in MS Excel.

	A	B	C	D	E	F	G	H	I	
1	RESULTS	iron	Plastic	tin	AL	wood	Stainless steel	Iron Alone	R+PL	
2	FV1	0	0	0	0	0	1	0	1	
3	FV2	0	0	0	0	0	0	0	0	
4	FV3	0	0	0	0	0	0	0	0	
5	FV4	0	0	0	0	0	1	0	0	
6	FV5	0	0	0	0	0	1	0	0	
7	SUM	0	0	0	0	0	3	0	1	
8	MAX	Stainless steel								
9										

Fig.5 Excel sheet showing max sum concept

The software for this research was developed using MATLAB version 7.02 and MS EXCEL 2010. Both are working on Microsoft Windows 7 platform.

3.3 SOFTWARE MODULES

The Software has basically 4 modules:

1. Pre-processing
2. Feature Extraction
3. Recognition
4. Output

3.4 SYSTEM VALIDATION

Software system validation is the documented process of assuring that a computer system does exactly what it is designed to do in a consistent and reproducible manner. The

	A	B	C	D	E	F	G	H	
1	Material	Polarization Angle	Mean c	Std Devial	GLCM - ' Contrast	GLCM- Correl	GLCM-Energy	GLCM-Homog	
2	Stainless steel		0	148.6	43.31592	0.110129421	0.963691076	0.203369685	0.944986442

validation process begins with the system proposal/requirements definition and continues until system retirement and retention of the e-records based on regulatory rules.

For validation purpose we provide the software with test images of two materials

1. Material 1 is rubber tyre with plastic alloys
2. Material X (not in database)

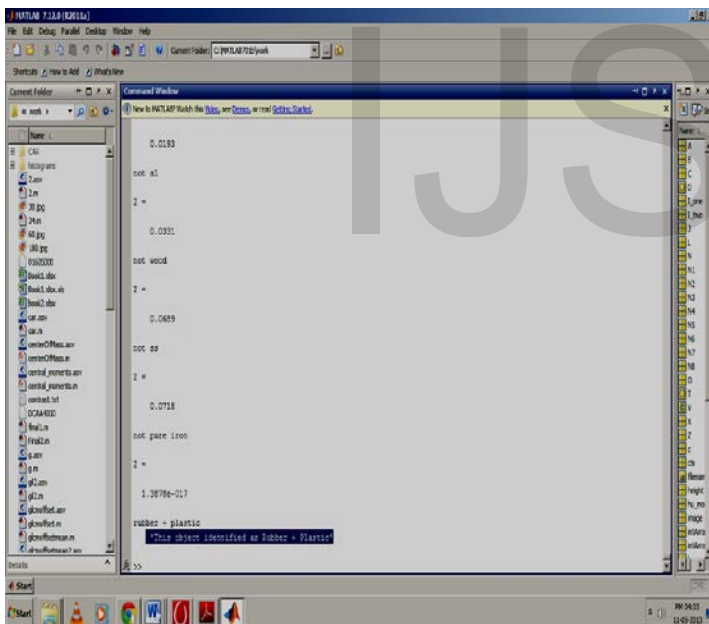
The aim of the software is to recognize the material by comparing it with the training image database.

4 Conclusion

The MATLAB code was successful and material 1 was recognized as a material with rubber and plastic composition i.e. a tyre with plastic alloys and material X was not identified as it was absent from database. Some errors occurred due to following problems:

- Intensity variation
- Noise
- Disturbance

These errors were removed for smooth operations.



The proposed concept or solution is working and it can be further optimized to increase the accuracy. This can be done by extracting more feature vectors, increasing the training image database size and using more sophisticated recognition algorithm.

While Polarization Vision by itself for detecting and recognizing targets is not fool proof, preliminary empirical results show that to evade some of the additional capabilities afforded by polarization sensing would require significantly more sophisticated countermeasures than are currently being used. In combination with Automatic Target Detection and Recognition methodologies using other sensor modalities such as mul-

tispectral visible and FLIR, as well as LADAR sensing, preliminary experimentation with Polarization Vision appears to provide a new domain of complementary information supporting fusion with these other modalities for increased effectiveness.

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